UNIVERSITEIT TWENTE.

Faculty of Science and Technology

Programme-specific appendix to the programme part of the students' charter, including the education and examination regulations of the

Advanced Technology

Bachelor's Programme

(art. 7.13 and 7.59 WHW)

Contents

Preamble

1. The rules in this appendix apply to the full-time Advanced Technology Bachelor's programme.
2. Together with the Common Part (TNW17066/vdh) this appendix forms the programme section of the student charter for the bachelor's programme Advanced Technology of the faculty Science and Technology at the University of Twente.
3. The Examination Board has set rules for the purpose of the conduction of its tasks and prerogatives (WHW art.7.12) in the "Rules and regulations of the Examination Board of Advanced Technology".

Reference: TNW/17067/vdh/em
Date: 20 July 2017

Article 1 Programme Objectives

The international bachelor's programme Advanced Technology aims to impart knowledge, skills and insight to the graduate regarding the field of Science and Technology by means of a broad-based and exploratory curriculum in such a way that the graduate is able to apply these skills in a global context to develop new technologies that are both economically and socially viable and to make a well-considered choice for one of the University of Twente master's programmes or a master's programme at another university in the Netherlands or abroad as well as use these skills to successfully finish the programme of their choice. For graduates who wish to enter the labour market after acquiring their bachelor's diploma the programme offers the opportunity of giving a more concluding character to the third and final year of the curriculum.

Article 2 Connecting master's programmes

If the bachelor's final examination has been taken, admission can be obtained to one or more master's programmes of the University of Twente or another university in the Netherlands or abroad, depending on the selected course list in the second and third year of the programme. The conditions which have been stipulated for the mentioned course list are specified in article 6 of this appendix and article 10.4 of the Advanced Technology Examination Board Rules.

Article 3 Language

1. The language used in the study units of the Advanced Technology bachelor's programme is English. This applies to both teaching and examination.
2. The Examination Board can grant permission to conduct an examination in a different language.
3. In course evaluations and student panel meetings the quality of the English language proficiency of teaching staff will be a standard subject. If necessary resulting from evaluation outcomes, the programme board will urgently appeal for the involved staff member to improve his/her English proficiency.

Article 4 Programme intended learning outcomes

A graduate of the Advanced Technology Bachelor's programme:

1. Domain knowledge & skills

Can apply basic theoretical concepts, important methods and techniques in the fields listed below and has skills to increase and develop this through study:

1. Elements from mechanical engineering, electrical engineering, physics, chemistry (Newtonian dynamics, Thermodynamics, Material Science, Mechatronic systems, electromagnetism, System Engineering).
2. Mathematics and programming.
3. Innovation, business administration and development/trends of technology on a local and a global level.
4. Analysis of impact of technology on a local and a global level.
5. Experimentation in the technical sciences.

2. Research & Design

a. is able to apply the scientific research method.
b. is able to apply the scientific design methods and is able to divide a design problem in different sub problems.

3. Organize

Is able to organize work both independently and as a member of an international project group. In project work able to define separate problems for team members, to assure the interconnection between these entities and to implement a timeline.

4. Report & Presentation

Is capable of communicating on technical-scientific issues both in writing and orally in a clear, concise and professional manner.

5. Problem solving

Is capable of analysing, modelling, interpreting and solving technical-scientific problems with an academic approach, i.e., formulating a problem definition, selecting scientific information and processing it, conducting research and critically evaluating the subsequent results, and of formulating conclusions.

6. Personal Development

Is able to recognize personal strengths and weaknesses as well as personal interests that are necessary to opt for either a follow-on study, in particular an academic master's programme which requires a high level of autonomy or a job in the labour market.

Article 5 The bachelor's exam

The bachelor's exam of the programme contains programmes of the first, second and third course year (B1, B2 and B3). The core programme consists of the B1-, B2-programme plus two modules of the B3 programme (total 150 EC) of the AT curriculum.

Typical educational forms are lectures, tutorials, lab work, assignments, projects and problem based learning. Tests of the subjects are in the form of written exams, oral exams, reports, presentations and posters.
The module intended learning outcomes of each module of the AT curriculum can be found in Appendix 1.
More information on the contents of the modules and subjects is available in the Osiris Course Catalogue.

The B1-programme has a study-load of 60 EC and consists of 4 modules of 15 EC each, with the module parts defined below:

Module	Course code / Name	Content / Module parts	Category[1]	EC	
1	201700090 Mechanics	- Calculus 1 - Mechanics - Laboratory Practice 1 - Project Mechanics	A B C C	4.0 4.5 3.5 3.0	15
2	201700091 Thermodynamics	- Calculus 2 - Thermodynamics - Laboratory Practice 2 - Project Thermodynamics	A B C C	3.0 4.5 3.5 4.0	15
3	201700092 Fundamentals of Materials	- Vector Calculus - Materials - Analysis of Technology in Societal Context	A B B	3.0 9.5 2.5	15
4	201700093 Dynamics	- Linear Algebra - Dynamic Systems - Instrumentation - Project Accelerometer	A B C C	3.0 4.0 4.0 4.0	15
	Total B1				60

For students of cohort 2016 and before transitional arrangements are in effect.

The B2-programme has a study-load of 60 EC. The second module (module 6) consists of a one out of three module choice. The modules of the B2-programme with the module parts defined below are:

Module	Course code / Name	Content / Module parts	EC	
5	201700095 Signals, Models and Systems	- Signals and Models - System Analysis - Project	10.0 2.0 3.0	15
6a	201700097 Materials Science and Engineering	- Advanced Materials - Chemistry and Technology of Inorganic Materials choice 1 of 2 - Semiconductor Devices - Physical chemistry	5.0 5.0 5.0 5.0	15
6b	201400162 Transport Phenomena	- Transport Phenomena - Numerical Methods - Project	7.5 3.75 3.75	15
6c	201700076 Systems and Control for AT	- Electronics - Engineering System Dynamics - Control Engineering - Project	4.0 4.0 4.0 3.0	15
7	201700143 Fields and Waves	- Electro- and Magnetostatics - Project Antenna - Finite Element Methods	9.0 3.0 3.0	15
8	201700144 System Engineering, Entrepreneurship and Knowledge Production	- System Engineering - Entrepreneurship and Innovation Management - Knowledge Production in Innovation	6.0 4.0 5.0	15
	Total B2			60

For students of cohort 2015 and before transitional arrangements are in effect.
The B3-programme consists of 4 modules of 15 EC each and has a study-load of 60 EC. One of these modules is the Bachelor assignment. The modules of the B3-programme should be chosen in such a way that admission to one of the

[1] Categories are defined for the determination of the binding recommendation on continuation of studies as stated in article 9a, paragraph 1b.

master’s programmes referred to in article 2 of this appendix is obtained. The admission requirements for a selection of master’s programmes are available on the AT website. The selected subjects in the third-year curriculum requires the approval of the Examination Board.

The B3 programme consists of 4 modules of 15 EC each and has a study-load of 60 EC with the module parts defined below:

Module	Course code / Name	Content / Module parts	EC	
9,10,11	Elective modules (of which typically two are needed for admission to the master of choice)			45
12	201700099 Bachelor Assignment	- Scientific/Design - Communication (report & presentation) - Work process	6.0 4.5 4.5	15
	Total B3			60

For students of cohort 2014 and earlier transitional arrangements are in effect.

There are three B3 elective modules offered by the Advanced Technology programme. Each module consists of 15 EC with the module parts defined below:

Module	Course code / Name	Content / Module parts	EC	
9	201700072 Science	- Introduction Solid State Physics - Statistical Physics - Optics - Molecular Structure and Spectroscopy	5.0 5.0 2.5 2.5	15
10	201700182 Materials for the Design of the Future	- Physical Chemistry - Interfaces and Interactions in Composite Materials (IICM) - Project	5.0 5.0 5.0	15
11	201700098 Micro System Design and Realization	- Micro Electro- Mechanical Systems Design - Transducers - Design verification with FEM - Preparation Bachelor Assignment AT	5.0 3.0 3.0 4.0	15

Article 5a Period of validity of module part results

1. The following rules apply to the modules of the B1 and B2 programme (module 6b, Transport Phenomena excluded) and the modules Science (module 9, 201700072), Materials for the Design of the Future (module 10, 201500064) and Micro System Design and Realization (module 11, 201700098).
   a. A module part result is a pass (or sufficient) if the mark is a 5.5 or higher or a “sufficient” qualification (denoted by the letter “V”) is obtained.
   b. When a module has not been successfully completed, the period of validity of the module part results is unlimited, unless the Examination board has restricted this period because the Examination board has determined that the knowledge or skills are proven to be out of date. The unlimited validity does not apply to the module part results of the (module 12, 201700099) Bachelor Assignment.
2. The rules of validity of the module part results of module 6b Transport Phenomena are determined by the Chemical Engineering programme.
3. For an elective module, the rules of validity of module part results of the programme that offers the elective module apply.
4. In all other situations, the Examination Board may grant an extension of the validity of module part results, at the request of the student, on an individual basis and depending on the circumstances.

Article 5b Plus programme

AT students can take additional courses as part of the 30 EC “Plus Programme” under the following conditions:

1. At the start of the plus programme the student must have passed all previous modules.
2. Suitable candidates for participation in the plus programme will be invited by the programme board. More information about the selection criteria will be published on the Advanced Technology programme's website. One of the criteria will be the module grades.
3. In case a participant of the plus programme fails a module of the regular programme, participation in the plus programme will be suspended till the moment the student has passed all previous modules again.

4. Courses can be taken from the selected plus programmes that are offered.

5. The plus programme will be registered on the diploma supplement as “Plus Programme courses” when 30 EC of plus programme courses have been passed. When less than 30 EC of the plus programme has been obtained the courses will be registered under “Additional courses” without reference to the plus programme.

6. In special circumstances the programme board can deviate from the rules in clauses 1-5 of this article.

Article 6 Transitional arrangements

1. If the study programme in article 5 of this appendix is changed, or if one the articles included in the common part of the OER or programme appendix change, the programme board will stipulate and publish transitional arrangements.

2. The transitional arrangements have to comply to the conditions set in article 8.4 of the common part of the OER.

3. The transitional arrangements are valid for the year of publication and are updated every year.

4. The transitional arrangements are published on the Advanced Technology programme's website.

Article 7 Safety

Before being allowed to work in a laboratory space, specific safety requirements may apply. Students are required to inform themselves about these rules[2] and to adhere to them.

Article 8 Sequence of study units (courses)

1. Before starting a study unit, students must meet the prior knowledge requirements of that study unit.
   a. Students may only take the (201700095, module 5) Signals, Models & Systems module when the (201700090, module 1) Mechanics module has been passed.
   b. Students may only take the (201700097, module 6a) Materials Science and Engineering module when the (201700092, module 3) Fundamentals of Materials module has been passed.
   c. Students may only take the (201700076, module 6c) Systems and Control for AT module when the (20170090, module 1) Mechanics, (201700093, module 4) Dynamics, and (201700095, module 5) Signals, Models & Systems modules have been passed.
   d. Students may only take the (201400162, module 6b) Transport Phenomena module when the (201700091, module 2) Thermodynamics module and the Vector Calculus part of the (201700093, module 4) Dynamics module have been passed.
   e. Students may only take the (201700143, module 7) Fields and Waves module when the Vector Calculus part of the (201700093, module 4) Dynamics module has been passed.
   f. Students may only take the (201700144, module 8) System Engineering, Entrepreneurship and Knowledge Production module when the (201700091, module 2) Thermodynamics, (201700092, module 3) Fundamentals of Materials and (201700093, module 4) Dynamics modules have been passed.

2. Students may only start with a B2 study unit when the B1 study unit of the same quartile has been completed.

3. Students may only start with a B3 study unit when the B2 study unit of the same quartile has been completed.

4. Students may only participate in minor modules (see article 3.2.2.e of the common part of the OER) after having obtained at least 75 EC and passed modules 1, 2, 5 and 6.

5. Students may only start the bachelor assignment after completion of the core programme (the core programme consists of the B1-, B2-programme plus two modules of the B3 programme, total 150 EC).

6. The programme board is authorised to deviate from the requirements set in clauses 1 to 5 of this article, in the event that strict adherence would result in an unreasonable delay in study progress. Students can submit a request for this to the programme board.

Article 9 Student counselling

1. The study advisor has the task of individually advising the students on all aspects of their studies and informing the programme board on the study progress of the students.
2. The study advisor actively communicates with the students with a progress rate less than 75% of the nominal rate of 60 EC/year.
3. After the first year, the study advisor invites the students at least once a year for a progress meeting.

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[2] For B1 and B2 laboratory practice work, see the 'Health & Safety and Environmental Regulations' on https://www.utwente.nl/tnw/intranet/diensten/amh/ and the information of the Science and Technology Laboratory Practice Group, on https://www.utwente.nl/tnw/slt/. For different kind of labs other safety requirements may be valid.

Article 9a Binding recommendation on continuation of studies (BSA)

1. A student receives a positive final recommendation on continuation of studies in accordance with article 6.3 of the common part of the OER if he has obtained 75% of the first year study load and meets the additional requirements. This is the case if either:
   a. the student passed 3 of the 4 modules of the B1 programme in accordance with the rules set in the assessment plan of the modules, or
   b. the student completed a total of 45 EC's of the module parts as determined in the B1 programme in article 5 with a mark of a 5.5 or higher or a mark as sufficient (denoted by the letter "V"), while the student has no more than one insufficient grade in each of the categories A (mathematics), B (theory) and C (project or practicum) as mentioned in the B1 programme in article 5.

2. In all other cases the student will receive a binding recommendation on continuation of studies (BSA).

Article 9b Quality assurance

1. The programme board is responsible for the evaluation of the programme.

2. The execution of the internal quality assurance of the Advanced Technology programme is delegated to the Quality assurance coordinator of the Science & Technology faculty. The Quality assurance coordinator is the chairman of the Quality assurance committee.

3. For the internal quality assurance, the following instruments are used:
   a. panel meetings with students;
   b. the UT Student Experience Questionnaire (UT-SEQ);
   c. web surveys about the entire module or module parts[3];
   d. overview of quantitative results, such as passing rates;
   e. lecturer panel meetings in which the lecturers and some students of the panel meeting are present; point of discussion are the evaluations mentioned in points a-d.

4. The outcomes of the internal quality assurance are published in the following ways:
   a. for each module, based on the minutes of the in article 9b.3e. mentioned lecturer panel meetings, an evaluation report is set up; this evaluation report will be sent to the involved lecturers, the staff of the programme and the programme committee;
   b. overviews of the quantitative results, summaries of the web-surveys and evaluation reports are published on the Blackboard organization Quality assurance and evaluation AT, which is accessible to all students and lecturers of the Advanced Technology programme.

5. The following internal and external evaluations are used to evaluate the curriculum and the entire programme:
   a. an exit-survey about the entire bachelor's programme;
   b. the National Student Enquiry (NSE);

   The programme board gives a response to these evaluations, accommodated with a plan for improvement. The evaluations and plan for improvement are submitted to the programme committee.

6. Each year, the programme board sets up a plan for improvement, which is based on internal and external evaluations and new insights.
   a. The plan for improvement will be discussed in the programme committee.
   b. The plan for improvement will be included in the faculty's annual plan.
   c. The faculty's annual plan will be discussed by the dean and portfolio holder for education with the executive board in the fall meeting.

Article 10 Change

In case of changes to the programme specific appendix articles 8.3 and 8.4 of the common part of the OER apply.

Article 11 Effectuation

These regulations will come into effect on 1 September 2017 and replace the regulations dated 1 September 2016.

Established by the dean of the faculty, in due consideration of the recommendations of the faculty council and the programme committee and the consent of the faculty council to articles 5a, 9a and 9b.

Enschede, 20 July 2017.

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[3] Web surveys are used when a module is new or largely renewed, or when the overall grade for the entire module or a module part in the UT-SEQ or the previous web survey was lower than 6.0.

Appendix 1 Module intended learning outcomes

1. Module 1: (201700090) Mechanics
   The student:
   a. Will have a thorough understanding of calculus with emphasis on differentiation and solving first and second order ordinary differential equations.
   b. Understands the relation between position, velocity and acceleration and can use this to solve two-dimensional motion problems.
   c. Understands and can apply basic linear and rotational mechanics such as static equilibrium, Newton's laws, conservation of momentum, angular momentum and energy.
   d. Can explain research methodology and apply this on a physical experiment and understands the importance of journalizing.
   e. Has an understanding of cooperation skills.
   f. Can write a scientific report and give a scientific presentation.
   g. Has knowledge of software to simulate and optimize a solution for a mechanical motion problem.

2. Module 2: (201700091) Thermodynamics
   The student:
   a. can explain the following thermodynamic concepts: differences between ideal gas and a real gas, the Van der Waals equation; triple point & critical point in PV/PT plots; specific heat CP and CV; differences between enthalpy & internal energy.
   b. can explain and apply the first and second law of thermodynamics.
   c. can explain and evaluate thermodynamic cycles (Carnot efficiency, Joule Thomson expansion).
   d. can derive thermodynamic identities (e.g., dU, dH, dG, en dF and determine changes in Gibbs and Helmholtz free energy.
   e. can work with limits, definitions of continuity and differentiability and applications, elementary properties of integrals and calculate integrals using different techniques, power series and Taylor series
   f. can investigate functions in two variables.
   g. is able to set up and to conduct a scientific experimental research in a systematic manner and document that research in a (pre)structured log book.
   h. is able to make an error analysis on the experiments performed, has knowledge of the basics of probability theory and statistics and can apply this to research questions and is able to program simple algorithms and to process measurement results using Matlab.
   i. is able to systematically design a system related to the theme of the module: problem analysis (requirements, weighing factors); functions and methods, alternative concepts and selection of conceptual design; develop a conceptual design into a detailed design, and conduct/interpret experiments to optimize the design and realization.
   j. is able to work in a team and present & defend results (written & oral).

3. Module 3: (201700092) Fundamentals of Materials
   The student:
   a. Can explain, from historical point of view, the evolvement of Quantum Mechanics evolved and give examples of applications of QM in modern Science & Technology.
   b. Can explain the Copenhagen interpretation of QM and use the Schrodinger equation to solve simple problems.
   c. Can explain the 3 main classes of materials on different levels (molecular to macroscopic), their mechanical properties in relation to the underlying structure.
   d. Can explain electrical properties of different materials (metals, insulators, semiconductors) in relation to the underlying structure, and predict the flow of electrons during chemical reactions.
   e. Can identify basic chemical structures, functional groups and connect chemical functions to molecular materials.
   f. Can search systematically for information, following a search strategy & write a group essay and present a poster on a given topic, and discuss findings.
   g. Has knowledge of technological development as social phenomenon and various patterns of technological development in societal context.
   h. Is able to read social science texts and summarize key concepts, skills to apply knowledge on concrete cases of technological development, innovation and implementation in society and ability to reflect on possibilities for policy and management of technological innovations.
   i. Will have a thorough understanding multivariate calculus.
   j. Will have a thorough understanding of vector calculus, including the application of the theorems of Gauss and Stokes.

4. Module 4: (201700093) Dynamics
   a. The student will be able to formulate mathematical models of moderately complicated physical problems (dynamics, mechanics, electrical networks) in terms of differential equations, ODEs.
   b. The student can apply several techniques to solve/approximate ODEs and understands the relation between time and frequency domain and can describe and use the basic properties of Fourier series and Fourier Transformation and use Laplace transform to solve a differential equation.
   c. The student will know how to simulate dynamical systems using software like Matlab, Multisim, and to use Mathematica for analytic results.
   d. The students will further improve their experimental skill and scientific attitude.

e. The student will have a (very) basic understanding of microcontroller systems, analogue-to-digital and digital-to-analogue conversion.
f. The student will have a basic understanding of electronic components and can evaluate and design elementary circuits.
g. The students will further improve their reporting, presentation and communication skills.
h. The student can work with systems of linear equations, vectors, matrices, linear transformations and explain the connections between these concepts.
i. The student can work with subspaces of Rn, determinants and eigenvalues/ eigenvectors and connect them with the previous concepts.
j. The student is able to formulate design criteria from a chosen area of application of a product. The design is validated with a dynamical systems analysis. Tests on the build system are made to verify the design criteria and to formulate design improvements.

5. Module 5: (201700095) Signals, Models & Systems
The student can:
a. create a description of physical (electrical, thermal, mechanic and physical transport) systems in terms of a set of (ordinary) differential equations, using principles like conservations laws and continuity relations.
b. describe a distributed system as a set of linked lumped systems.
c. solve analytically the response of a system described by a set of differential equations in terms of stability, eigenvalues and eigenmodes and is able to interpret the solutions.
d. analyze system behaviour through simulation tools and discuss the validity of the model representing the system. Interpretation of system properties via the response of probe signals (pulse, step and trend). Understands the concept of transferfunction.
e. understand the relation between time and frequency domain and can describe and use the basic properties of Fourier series and Fourier Transformation and use Laplace transform to solve a differential equation.
f. understand the difference between the continuous and discrete time and frequency domain and can perform a discrete Fourier Transform and use z-transform techniques to solve a differential equation
g. choose a correct digital sampling frequency and can design a digital filter with the aid of z-transform techniques.
h. apply first order statistical methods (correlation techniques) to analyze and describe stochastic signals.
i. understand the principles and the influence on stability of feedback.
j. implement a P, PI or PID controller in a system control design
k. understand and develop a small Labview program to control a measurement.
l. define a design/research project and function as project team member, name milestones in the project and defend the choices made to achieve the goals set by the milestones.
m. report on results from a design/research project and reflect on the quality of this work.

6. Module 6a: (201700097) Materials Science and Engineering
The student can:
a. calculate diffusion processes in solid and crystalline materials, the value of a characteristic parameter (saturation magnetization, polarization) by simple models, apply Weibull statistics to evaluate fractures in materials.
b. explain binary phase diagrams of metals and oxides and the influence of thermodynamics and kinetics of phase transitions on the microstructure.
c. regarding the properties of materials: determine the material class by a global description of its properties (electrical, magnetic) , and provide for a specific, technological material:
    1. a description of all primary mechanical and functional properties (magnetic, electrical, optical, etc.).
    2. an explanation of the properties on the structure, taking care of the fact that different phenomena at different length scales play a role.
d. explain the relation between properties, structure/composition and synthesis for inorganic materials; Explain epitaxial growth and strain within materials.
e. describe the principles of the commonly used physical vapour deposition techniques and chemical vapour deposition techniques for films; describe the principles of sol gel and sintering techniques for bulk materials.
f. apply, for a particular practical situation of a functional material in an actual device, the separation between function, properties and fabrication requirements.
g. describe the central ideas in colloid science (like surface energy, adsorption, wetting, surface potential, electro-osmosis, electrophoresis and colloidal stability); the central ideas in transport of the reactants/products to/from the catalyst (Molecular and Knudsen diffusion, internal and external mass transfer limitations, Thiele modulus); the assumptions of Langmuir-Hinshelwood en Eley-Rideal mechanisms.
h. analyze experimental data, find kinetic parameters; describe and interpret results from important characterization techniques (chemisorption, electron microscopy, STM, XRD, XPS, LEED); and use expressions for capillary rise / pressure, adsorption isotherms and electrical double layers.
i. predict the apparent activation energy for a catalysed reaction in the case of no/ internal/ external mass transfer limitations.
j. explain the following concepts: energy band diagrams and their importance for devices; the drift-diffusion equations; recombination; "depletion approximation" and charge conservation; threshold voltage.
k. explain the formation of the pn-junction diode at thermal equilibrium, the rectifying behaviour of the pn-junction diode, the formation of the MOS capacitor at thermal equilibrium.
l. model the current flow through the pn-junction diode in steady state condition, and the current flow through the MOSFET in steady state condition and apply Gauss' law in a semiconductor for determining the electric field/potential.

m. explain the advantage of using semiconductor devices in microelectronics and evaluate the limiting factors in electrical performance of classical semiconductor devices and come up with possible improvements.

Module 6b: (201400162) Transport Phenomena

Fluid Dynamics

a. Being able to formulate and solve a macroscopic balance for mass, momentum and/or energy in case of flow through a control volume
b. Being able to determine the velocity and shear stress profile for fluid flow through simple geometries (2D, 3D tube flow), starting from the micro-balance for momentum, for different boundary conditions (gas-solid, liquid-solid, liquid-gas). Being able to calculate the flow rate and force exerted to the wall by the fluid.
c. Understand terms as Reynolds number, laminar flow and turbulent flow. Being able to use these terms in the right context.
d. Able to apply Bernoulli's Law for flow at high and at low Reynolds numbers.
e. Able to determine the flow resistance for piping systems and for flow past objects of simple geometry (spheres, cylinders)
f. Able to formulate and solve the equation of motion for particles moving in a fluid under influence of gravity and/or uplift

Heat and Mass Transfer

a. Able to recognize the prevailing transport mechanisms. Able to describe quantitatively heat transport by conduction, convection and radiation, separately and combined. Formulate and solve integral and differential thermal energy balances for steady state and instationary operation of open and closed systems.
b. Formulate and solve differential energy balances and component mole balances to find a temperature distribution or concentration profile.
c. In this, the necessary and appropriate various (integral or differential) energy and mole balances and transport (Nusselt/Sherwood) correlations must be applied.
d. Knowledge of mass transfer models and be able to describe quantitatively mass transport in a single phase by diffusion and convection, as well as mass transfer between phases. Able to solve problems of coupled heat and mass transport. Apply appropriate Nu/Sh correlations.
e. Analyse and solve problems on thermal energy and molar transport in exchange equipment. Formulate and solve integral and differential, stationary (component) mass- and energy balances.

Numerical Methods

a. Knowledge of MATLAB as modelling platform, basic programming skills, being an independent user, able to write and run a script, generate numerical and graphical output.
b. Recognize and able to solve Ordinary Differential Equations (ODE). Being familiar with most use methods in the Matlab Toolbox to solve ODEs and being able to apply these.
c. Knowledge of numerical solution methods, finite difference, stability and truncation errors etc. Being able to apply this knowledge when solving (a set of) non-linear equations.
d. Recognize and able to solve Partial Differential Equations (PDE's) using tools available within Matlab and finite difference methods.

Module 6c: (201700076) Systems and Control for AT

a. Understanding of the dynamic behavior of physical systems.
b. Knowledge on how to model, analyze, and simulate the dynamic behavior of physical systems that belong to various physical domains.
c. Ability to analyse, design and realize an electronic circuit that works above one MHz.
d. Understanding of the design and realization of a feed-forward and a state-feedback control of linear/linearized dynamic systems.
e. Ability to make a stability and sensitivity analysis of a control system.

7. Module 7: (201700143) Fields and Waves
    a. The student is able to use Maxwell's classical theory of electromagnetism to describe and evaluate electromagnetic fields and waves produced by electric charges, which are either stationary (producing static electric fields), moving at constant velocity (producing static magnetic fields) or accelerating (leading to emission of absorbtion of electromagnetic waves).
    b. Using force- and potential fields, the student will be able to calculate forces acting on charges that are stationary or moving at constant velocity and understand the extension of Maxwell's field theory to describe other physical phenomena, such as gravitational forces or heat flow.
    c. The student can calculate fields by means of summation (integration) over sources and can apply integral rules (Gauss's- and Stokes's laws) in case of highly symmetric charge- or current density distributions.
    d. The student is able to design, construct and test a sending antenna for a wireless communication device. The working of a finite elements method (COMSOL) is understood and is applied to calculate electromagnetic radiation (antenna patterns and impedance) to optimize the antenna design.
    e. The student understands how electric fields behave inside linear, isotropic materials.
    f. The student will have a view on how an international science organization sets its goals, operates and what the engineering issues are related to the domain of Advanced Technology.
    g. The student is able to work in a group to gain knowledge in a Problem Based Learning style.

8. Module 8: (201700144) System Engineering, Entrepreneurship and Knowledge Production
   The student can:
   a. combine product/system, scenarios and business model into a coherent analytical package-deal; i.e. the development, the commercialization, and the future use of a complex technological system.
   b. present in both written and oral form a problem and its possible solution for both expert and non-expert audiences, by using and combining the course concepts.
   c. reflect upon working practices within the own field of expertise, as well as upon the broader social context in which engineering sciences develop and are applied.
   d. define a system that is viable from various perspectives (user, developer, producer, etc.).
   e. translate stakeholder requirements into a consistent set of "System Performance Specs".
   f. make a system design (breakdown the system into modules; make budgets, linking system performance to module performance design of at least one sub-system; make an integration & test plan; make a risk assessment).
   g. define, analyze and reflect on a firm's business model and its constituting elements (such as value proposition, customer segments, and revenue streams).
   h. understand the key factors of effective team work and reflect on the effectiveness of their own team work.
   i. combine understanding of the business development process with an analysis of an firm's external environment (incl. customer needs) to develop a business case for new business opportunities.
   j. analyze innovation as processes of knowledge production by using theoretical course concepts.
   k. become acquainted with a number of foresight study methods (trend analysis, Delphi method, forecasting, backcasting; road mapping).
   l. write future product use scenarios in which society, markets, and users/consumers/citizens play a crucial role.

9. Module 9: (2017000072) Science (elective)
   After this course the student:
   Statistical Physics
   a. understands how microscopic partition functions are determined by the atomic composition of a system;
   b. can derive partition functions for simple systems;
   c. can relate microscopic partition functions to macroscopic thermodynamic potentials;
      can apply these relations to simple systems;
   d. knows the crucial differences between classical (Boltzmann) and quantum mechanical (Fermi-Dirac, Bose-Einstein) systems.
   e. can interpret thermodynamic data in terms of microscopic behaviour.

   Introduction Solid State Physics
   a. can identify the structure of a crystal lattice, and its reciprocal lattice
   b. is able to calculate a diffraction pattern and invert it back;
   c. can describe the concept of phonon dispersion relations and determine the thermal properties of a solid (Debye & Einstein models, thermal expansion);
   d. is able to calculate a 1D phonon dispersion relation;
   e. can determine the electronic configuration of an atom;
   f. can compare the conductivity of a metal with the free electron model;
   g. can describe the behaviour of electrons in a periodic potential and explain the concept of a band structure

   Molecular structure and spectroscopy
   a. is able to understand, explain and apply the physical principles of the Valence-bond theory and the Molecular orbital theory for chemical bonding;
   b. understands and is able to apply the hybridization of orbitals;
   c. can derive the electronic structure and bond order of homo- and heteronuclear diatomic molecules;
   d. can analyse the electronic structure from photoelectron spectroscopy data;
   e. can describe general features of molecular spectroscopy
   f. discriminates between the underlying photophysical processes of rotational, vibrational and electronic spectroscopy
   g. is able to understand, explain and apply the physical principles of rotational, vibrational, electronic spectroscopy

   Optics
   a. is able to understand and explain basic concepts of geometrical optics (reflection/refraction, Fermat's principle, lens equation).
   b. is able to understand and explain basic concepts of physical optics (electromagnetic waves, plane waves, superposition, interference, diffraction)
   c. can apply the aforementioned concepts to analyse, design and execute optical experiments

10. Module 10: (201700182) Materials for the Design of the Future (elective)
    The student:
    a. understands how material properties are related to structure and composition of a material.
    b. can explain manufacturing technologies and is able to select an appropriate technology for a specific problem.
    c. can explain the principles of various techniques for material structure and composition characterization and select the appropriate techniques for a specific problem.

d. can search and find relevant literature and locate state of the art research on a materials science topic. Is able to use this information for a literature study that provides an advice for materials choices to realize (at first hand conflicting) functionalities.
e. is able to summarize the information from literature in a state-of-the-art overview.
f. can elaborate an advice for material choices to realize (at first hand conflicting) functionalities. Requirements of sustainability, environmental and health hazards, recyclability etc. have to be included.
g. can specify the requirements for a certain functionality.
h. can design a material to fulfil the technical functionality.
i. can evaluate the design from a technical and social view and formulate the impact for humans and society.

11. Module 11: (201700098) Micro System Design and Realization (elective)
The student can:
a. design a micromechanical device or systems (sensors, actuators and fluidic devices or systems) based on a fixed fabrication process.
a. label a certain transducer in categories dealt with in the course.
b. calculate strain and stress in both axially and transversely loaded beams.
c. design a simple elastically deforming structure with optimal placement of sensing elements using the basic physics of metal and semiconductor strain gauges (piezo-resistive transduction).
d. derive the potential energy function for generator type transducers and based on this perform equilibrium and stability analysis.
e. explain the relation between the potential energy function of a generator type transducer and its small signal parameters.
f. set-up a Finite Element calculation in a package like COMSOL for a multi-domain (electro-mechanical) problem and validate the result of the calculation.
g. identify relevant literature for a BSc assignment, set up a literature reference base and is able to summarize the status of the international field on this topic.
h. identify a relevant BSc research question and can formulate this question and the required research plan.

12. Module 12: (201700099) Bachelor Assignment
The student can:
a. analyze a problem with some complexity in the field of Advanced Technology.
b. prepare, execute and analyze experimental or theoretical research in Advanced Technology.
c. design, build and test a device.
d. write a scientific report describing the result.
e. give an oral presentation of the results to an audience of peers and is able to answer questions on the subject.
f. self-sufficiently in organizing the work.
g. collaborate and interact with the scientific staff of a research group.