Werktuigbouwkunde 3TU OW 2012

Mechanical Engineering programmes
Delft University of Technology

Quality Assurance Netherlands Universities (QANU)
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
Telefax: +31 (0) 30 230 3129
E-mail: info@qanu.nl
Internet: www.qanu.nl

Project number: Q286

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This report was finalized on 30 November 2012.

Report on the bachelor's programme Mechanical Engineering and the master's programme Mechanical Engineering of Delft University of Technology

This report takes the NVAO's Assessment framework for limited programme assessments as a starting point.

Administrative data regarding the programmes

Bachelor's programme Mechanical Engineering

Name of the programme:	Mechanical Engineering
CROHO number:	56966
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Specializations or tracks:	
Location:	Delft
Mode of study:	full time
Expiration of accreditation:	31-12-2013

Master's programme Mechanical Engineering

Name of the programme:	Mechanical Engineering
CROHO number:	60439
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	BioMechanical Design, Control Engineering, Materials Engineering& Aplications, Precision and Microsystems Engineering, Solid & Fluid Mechanics, Sustainable Processes & Energy Technologies, Transportation Engineering
Location:	Delft
Mode of study:	full time
Expiration of accreditation:	31-12-2013

The visit of the assessment committee Werktuigbouwkunde 3TU OW 2012 to the Faculty of Mechanical, Maritime and Materials Engineering of Delft University of Technology took place on 20 and 21 September 2012.

Administrative data regarding the institution

Name of the institution:	Delft University of Technology
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

Quantitative data regarding the programmes

The required quantitative data regarding the programmes are included in Appendix 5.

Composition of the assessment committee

The committee that assessed the bachelor's programme Mechanical Engineering and the master's programme Mechanical Engineering consisted of:

- Prof. dr. J.K.M. de Schutter, professor in Mechanical Engineering, KU Leuven, Belgium;
- Prof. dr. ir. M. Vantorre, professor in Maritime Technology, Ghent University, Belgium;
- Prof. dr. ir. P. Van Houtte, professor in Material Sciences, KU Leuven, Belgium;
- Ir. G. Calis, Chairman Division of Mechanical Engineers of the Royal Institute of Engineers in the Netherlands, former manager of Stork group of companies;
- Ir. H. Grunefeld, Educational Development and Training, Centre for Teaching and Learning, Utrecht University;
- E.M. Porte, master student Mechanical Engineering, University Twente.

The committee was supported by dr. B.M. van Balen, who acted as secretary.

Appendix 1 contains the curricula vitae of the members of the committee.

Working method of the assessment committee

Preparation
The assessment of the bachelor's programme Mechanical Engineering and the master's programme Mechanical Engineering of Delft University of Technology (TU Delft) is part of a cluster assessment of ten Mechanical engineering degree programmes offered by three universities. The bachelor's and master's programmes Maritime Technology and the master's programmes Offshore and Dredging Engineering and Materials Science and Engineering of TU Delft are also part of this cluster evaluation. The assessment of these programmes will be described in separate reports.

The kick off meeting for the cluster assessment was scheduled on 4 September 2012. During this meeting the committee members received an introduction into the assessment framework and evaluation procedures and the committee agreed upon its general working method. The entire committee consists of nine members. For each visit a sub committee was composed that ensures the necessary expertise to evaluate the programme. Furthermore the domain-specific requirements and the most recent developments concerning the Mechanical Engineering domain were discussed. These domain-specific requirements and the actual context form the starting point for the evaluation of the quality of the degree programmes.

In preparation of the assessment of the programme a self-assessment report was prepared by the programme management. This report was sent to QANU and, after a check by the secretary of the committee to ensure that the information provided was complete, forwarded to the committee members. The committee prepared the site visit by studying the self-assessment report and a number of Bachelor's and Master's theses (bachelor mini-paper and master graduation report, respectively). The secretary of the committee selected for the Delft bachelor programmes 17 bachelor and 22 master theses randomly and stratified, out of a list of all graduates of the last two years per programme. The following stratification is used: one third of the theses for each degree programme with low grades (6-6.5), one third of the theses with middle ranged grades (7-8) and one third of the theses with high grades. QANU asked the programmes to send the theses including the assessment by the supervisor and examiner and divided them among the sub committee members.

When a thesis was assessed as questionable or unsatisfactory by a committee member, a reassessment was done by another committee member. In the case that more than 10% of the theses were assessed as questionable or unsatisfactory by two committee members the selection of theses for the programme should be extended. This was not the case.

Site visit
The Committee members formulated questions raised by studying the self-assessment report in advance. These questions were circulated in the committee.

The Committee visited the programme on 20-21 September 2012. The programme of the site visit was developed by the Committee's secretary in consultation with the programme management and the chair of the Committee. The Committee interviewed, next to students, teachers and alumni, the programme management and representatives of the Faculty Board, the Examination Board and the student and teacher members of the Education Committee. An open office hour was scheduled and announced (but not used).

During the site visit the Committee studied additional material made available by the programme management. Appendix 7 gives an overview of all documents available during the site visit. The last hours of the site visit have been used by the Committee to establish the assessments of the programme and to prepare the oral presentation of the preliminary findings of the Committee to the representatives of the programme.

Report
The secretary wrote a draft report based on the findings of the committee. The draft report has been amended and detailed by the committee members. After approval of the draft report by the committee it was sent to the Department for a check on facts. The comments by the Department were discussed in the committee, this discussion resulted in some changes in the report and subsequently the committee established the final report.

The assessment was performed according to the NVAO (Accreditation Organization of the Netherlands and Flanders) framework for limited programme assessment (as of 22 November 2011). In this framework a four-point scale is prescribed for both the general assessment and assessment of each of the three standards. The committee used the following definitions for the assessment of both the standards and the programme as a whole.

Decision rules

Generic quality
The quality that can reasonably be expected in an international perspective from a higher education bachelor's or master's programme.

Unsatisfactory
The programme does not meet the current generic quality standards and shows serious shortcomings in several areas.

Satisfactory
The programme meets the current generic quality standards and shows an acceptable level across its entire spectrum.

Good
The programme systematically surpasses the current generic quality standards across its entire spectrum.

Excellent
The programme systematically well surpasses the current generic quality standards across its entire spectrum and is regarded as an (inter)national example.

General Assessment

- When standard 1 or standard 3 is assessed as 'unsatisfactory', the general assessment of a programme is 'unsatisfactory' .

- The general assessment of the programme can be good when at least two standards, including standard 3, are assessed as 'good',

- The general assessment of the programme can be excellent when at least two standards, including standard 3, are assessed as 'excellent'.

Summary judgement

Bachelor's programme Mechanical Engineering

Standard 1
The ambition of the *Bachelor's programme Mechanical Engineering* of Delft University of Technology (TU Delft) is to educate students up to an academic and internationally recognised level. Graduates will be engineers with a broad-based education and a thorough knowledge of the field. They can generate new solutions to problems by using initiative and acquired knowledge of science and technology. The international standards for the bachelor level are reflected in the intended learning outcomes, both in general terms and for the domain of Mechanical Engineering (ABET, OECD, ASME). The intended learning outcomes are transparent and specific and in line with the ambitions of the programmes. The Bachelor's programme, therefore, meets the criteria for standard 1 of the assessment framework.

Standard 2
The programme consists of a major in Mechanical Engineering (150 EC), which is equal and compulsory for all students, and a minor (30 EC) as elective part scheduled at the beginning of the third year.
The study programme has two principal forms:

- Course-based education, i.e. lectures/workshops ('colleges/instructies') with associated examinations.
- Projects in which students work together in project groups. Projects are primarily used to apply the earlier acquired knowledge in a realistic setting.

Learning lines ensure a logical increment of study contents and a build-up of knowledge and competences during the course years. Students experience the programme as fragmented with too many parallel courses. In September 2013, the courses will be clustered into larger courses, resulting in less examinations and more cohesion in the programme.

The programme has shown an increase in the number of VWO freshmen of approximately 45% since 2006 (per December 1st 2009: 253 VWO freshmen). Of these students, on average about 20% drop out during their first year up to 2009. Total drop-out during the programme appears to average in the order of magnitude of 30-40%.
It is expected that due to the introduction of the Binding Recommendation on Continuation of Studies in 2009 (Bindend Studie Advies (BSA)) the drop-out in the Bachelor's programme will shift largely to the first year.
In recent years actions have been taken to improve the success rate of students. Although the number of students who complete their Bachelor's in three years is very small, the committee is convinced - supported by comments of the alumni - that the programme is feasible.

The quantity and the quality of the teaching staff is adequate and so are the facilities. Quality assurance on programme level is functioning adequately. The committee was impressed by the creativity of the management to find solutions for the large numbers of students it has to accommodate. All physical spaces are used in a most efficient way to create room for the students for self-study and projects.

Standard 3
The committee has looked into the assessment system and the Bachelor's theses to assess if the intended learning outcomes are achieved. The committee is convinced that the assessment system is sufficiently valid and reliable. The committee has seen that the Board of Examiners is in control and has made a start with the implementation of an updated, adapted to renewed legislation, test policy. The Bachelor's theses are at the required level of an academic Bachelor's programme. Bachelor's graduates are well-prepared to continue their studies in an academic Master's programme.

The committee assesses the standards from the Assessment framework for limited programme assessments in the following way:

Bachelor's programme Mechanical Engineering:

Standard 1: Intended learning outcomes	good
Standard 2: Teaching-learning environment	satisfactory
Standard 3: Assessment and achieved learning outcomes	satisfactory
General conclusion	satisfactory

Master's programme Mechanical Engineering

Standard 1
The *Master's programme Mechanical Engineering* has the ambition to provide students with a profound educational basis allowing them to find excellent job positions after their graduation, either in industry or in academia. The Master's programme Mechanical Engineering of the TU Delft has a strong ambition and an internationally well known profile. The international standards for the master level are reflected in the intended learning outcomes, both in general terms and for the domain of Mechanical Engineering (ABET, OECD, ASME). The intended learning outcomes are transparent and specific and in line with the ambitions of the programme. The programme attracts a lot of students and graduates are sought after on the labour market. The committee was however not convinced of the added value of defining seven tracks, further subdivided into 17 specialisations within the Master's programme. Some of the tracks are strongly related to other Master's programmes. For example, there is a large overlap between the elaborate final qualifications of the track Materials Engineering and Applications and the Master's programme in Materials Science and Engineering. The committee suggests reconsidering this track structure, without losing the advantages of diversity in the programme.

Standard 2
The basic structure of the Master's programme is similar for all tracks. They have a nominal study length of two years and are equivalent to 120 EC. The tracks are composed of a first year with obligatory core courses, a specialisation part and elective courses, which students choose in consultation with one of the track coordinators or their mentor. Elective courses provide students the opportunity to deepen or broaden their knowledge. The second year consists of 60 EC and focuses on research.
During the second master's year students have a graduation professor and, usually, a daily supervisor as coach. An internship provides students with the opportunity to have first-hand experience in the domain of their choice and it confronts them with setbacks as they could encounter in professional life and the intellectual level that is expected of them after graduation. The teaching forms in the Master's programme are adequate, but not innovative.

The quantity and the quality of the teaching staff is adequate and so are the facilities. Quality assurance on programme level is functioning adequately. The committee was impressed by the creativity of the management to find solutions for the large numbers of students it has to accommodate.

Standard 3
The committee has looked into the assessment system and the Master's theses to assess whether the intended learning outcomes are achieved. The committee is convinced that the assessment system is sufficiently valid and reliable. The committee has seen that the Board of Examiners is in control and has made a start with the implementation of an updated, adapted to renewed legislation, test policy.
The committee studied a selection of Master's theses which indicate that the graduates have achieved the level that can be expected in a master's degree programme. Graduates of the Mechanical Engineering programme of the TU Delft easily find employment in the international field of industry and academia. The level that is achieved by the graduates of the programme is high.

Master's programme Mechanical Engineering:

Standard 1: Intended learning outcomes	good
Standard 2: Teaching-learning environment	satisfactory
Standard 3: Assessment and achieved learning outcomes	good
General conclusion	good

The chair and the secretary of the committee hereby declare that all members of the committee have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 30 November 2012

Prof. dr. J.K. De Schutter

Dr. B.M. van Balen

Description of the standards from the Assessment framework for limited programme assessments

The Bachelor's and Master's programmes Mechanical Engineering are offered by the Faculty 3mE of Delft University of Technology. Besides these programmes the Faculty 3mE also offers a Bachelor's and a Master's programme Marine Technology as well as five specific Master's programmes. The Marine Technology programmes and the Master's programmes Materials Science and Engineering and Offshore and Dredging Engineering are also assessed in this cluster evaluation. The assessments of these programmes are reported separately.

Throughout the report, the findings have been extracted from the self evaluation report, the interviews during the site visit and additional documentation provided by the programme management, unless mentioned otherwise.

Standard 1: Intended learning outcomes

The intended learning outcomes of the programme have been concretised with regard to content, level and orientation; they meet international requirements.

Explanation:
As for level and orientation (bachelor's or master's; professional or academic), the intended learning outcomes fit into the Dutch qualifications framework. In addition, they tie in with the international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the programme.

Findings

This section contains the committee's assessment on the profile and orientation of the bachelor's and the master's programme (1.1.), the domain-specific framework of reference (1.2.) and the intended learning outcomes (1.3.).

1.1. Profile and orientation of the programmes

The Bachelor's and Master's programmes Mechanical Engineering are offered by the Faculty of 3mE of Delft University of Technology (TU Delft). It is the ambition of this Faculty to educate committed engineers and PhD graduates and to conduct breakthrough scientific research in the fields of mechanical engineering, maritime engineering and materials science. It wishes to be an excellent example of a dynamic and innovative Faculty which pursues a leading position in Europe and makes a direct contribution to the economy and society.

The ambition of the Bachelor's *programme Mechanical Engineering* is to educate students up to an academic and internationally recognised level. Graduates will be engineers with a broad-based education and a thorough knowledge of the field. They can generate new solutions to problems by using initiative and acquired knowledge of science and technology. The graduates will have a broad scope, permitting them to take a broader economic, societal and socio-cultural context into account when looking for and implementing solutions, and when designing products and services. The bachelors will have an independent, creative and academic attitude and their thinking and actions shall be based on an international outlook.

The *Master's programme Mechanical Engineering* has the ambition to provide students with a profound educational basis allowing them to find excellent job positions after their graduation, either in industry or in academia. The Master's programme has seven specialisation tracks that have their own ambitions. The Biomechanical Design (BMD) aims to offer a broad and in-depth understanding of biomechanical engineering. Co-operation with

experts from a variety of other disciplines, including electrical engineering, informatics, biology, and medicine is sought, as the domain of biomechanical design is human centred-technology and strongly multidisciplinary. The track Control Engineering (CE) aims to deliver graduates with balanced academic and professional field competencies within their selected domains. The track wants to deal with the continuing demand for systems and control engineers who extend their expertise to adjacent technological disciplines. The track of Materials Engineering and Applications (MEA) aims to enhance knowledge of materials aspects related to design and manufacturing with relevance to a broad range of industrial and other applications. The track Precision and Mechanical Engineering (PME) has the ambition to educate students to become modern engineers that can tackle both the theoretical depth of high tech systems and the design aspects. The ambitions of the track Transportation Engineering (TE) are to maintain outflow of graduate students who will play a key role in developments in the transport domain. TE wants to especially emphasize the analysis, the modelling, the control and the design of complex transport systems and their components in an industrial context. The track Solid & Fluid Mechanics (SFM) has the ambition to teach students to work with state of the art tools in research in continuum mechanics.
The track Sustainable Process Energy Technology (SPET) aims to offer a unique combination of Process Technology and Energy Technology.

The committee has observed that the Mechanical Engineering programmes of the TU Delft have a strong profile in line with its ambitions. The programmes are internationally very well known. The programmes attract many students and graduates are sought after on the labour market. However, the committee was not convinced of the added value of defining as much as seven tracks, further subdivided into 17 specialisations, within the Master's programme. In the committee's view it is questionable whether this contributes to the transparency of the Delft's Mechanical Engineering profile. Some of the tracks also attract few students. The alumni interviewed by the committee told that graduates of TU Delft Mechanical Engineering easily find employment on an academic level but not necessarily related to their track. In fact the specifics of the tracks are not very well known in industry. The committee would recommend reconsidering the structure of the tracks and their specialisations. During the site visit the management of 3mE confirmed the observation of the committee that the number of tracks defined in the programme makes planning for both students as well as teachers unnecessarily complicated and inconvenient. The management assured the committee that it will reconsider the track structure.

1.2. Domain-specific framework of reference
The three collaborating programmes in Mechanical Engineering at the University of Twente (UT), the Eindhoven University of Technology (TU/e) and Delft University of Technology (TUD) have decided to use the ABET (Accreditation Board for Engineering and Technology) criteria as the basis for their domain-specific framework of reference, and to add the definition documents of the OECD (Organisation for Economic Co-operation and Development) and ASME (American Society of Mechanical Engineers).

The ABET criteria define the necessary elements of the curriculum: 'The curriculum must require students to apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations); to model, analyse, design, and realize physical systems, components or processes; and prepare students to work professionally in both thermal and mechanical systems areas.' The Tuning-AHELO Conceptual Framework of Expected/Desired Learning Outcomes in Engineering, published by the OECD in 2011, adds an emphasis on engineering skills in practice (theory and application), analysis (products, processes and methods) and design (apply knowledge to develop designs). ASME looks at what is expected of the future mechanical engineer (2028) who will be confronted with the challenges faced by society in developing sustainability, engineering large and small-scale systems, the competitive edge of knowledge, collaborative advantages, the nano-bio future, regulating global innovation, the diverse faces of engineering, designing at home and engineering for the other 90%. For a full description of the domain-specific framework of reference, see Appendix 2.

A benchmark of the three Dutch programmes and three foreign programmes (ETH, KTH, and University of Michigan) shows that the focus of the Dutch programmes is quite comparable. The committee is of the opinion that benchmark analyses of the perceived strengths of these institutes related to the assessment standards would contribute significantly to the self-evaluation and would possibly serve as indicators for the future development.

Furthermore, the committee feels that the co-operation between the three universities of technology (the 3TU co-operation) is a strong point. It helps to maintain a common basis for the programmes in mechanical engineering which makes student exchange between the three departments possible, while it also allows specific emphases per institute.

The committee found that the benchmark of the three foreign institutions did not have much added value because it did not go beyond a comparison of the elements of the curriculum contents. An analysis of the perceived strengths of these institutes would have been more useful as a guideline for the future development of the programmes.

The committee appreciates the Professional Review Committee, which meets twice a year, but recommends to make better use of this platform to collect feedback on the intended learning outcomes of the programme and the quality of the graduates in a more structured way.

1.3. Intended learning outcomes

The goal of the *Bachelor's programme Mechanical Engineering* is to educate students to the level of Bachelor of Science in Mechanical Engineering, enabling them to exercise the profession of engineer at a professional academic level. This means that graduates are able to:

- Identify, define and analyse problems, for the solution of which Mechanical Engineering principles and techniques can contribute;
- Systematically design and work out a sound solution;
- Effectively present this solution.

The Bachelor's programme guarantees admission to relevant Master's programmes. The following final qualifications have been defined for the Bachelor's programme Mechanical Engineering. A graduate has:

1. Broad and profound knowledge of the fundamental engineering sciences, which form the basis of Mechanical Engineering (mechanics, physical transport phenomena, thermodynamics, materials science, control engineering and mathematics), as well as some basic knowledge of related fields (electricity, magnetism, electronics, chemistry, informatics), to such a level that entrance can be obtained to internationally accredited Master of Science programmes Mechanical Engineering. The ability to apply this knowledge on mechanical engineering systems;

2. Basic technical scientific knowledge of the most important Mechanical Engineering disciplines: mechanical systems, process and energy technology, mechatronics and production technology. The ability to apply this knowledge to design such systems;
3. Basic knowledge of methods and tools for modelling, simulating, designing and executing experiments and research on mechanical engineering systems. The ability to apply this knowledge;
4. Capability to contribute to the solution of technological problems by a systematic scientific approach. This includes the analysis, the definition of innovative solutions, the evaluation of the feasibility, the recognition and acquisition of missing knowledge, as well as recognition of the relativity and limitations of knowledge and the working out of the solution;
5. Capability of working individually as well as in (multidisciplinary) teams, taking initiatives where necessary;
6. Capability to effectively communicate (including presenting and reporting) about one's work with regard to information, problems, ideas and solutions to both professionals and non-specialised public;
7. Capability to evaluate and assess the technological, societal and ethical impact of one's work and to take responsibility with regard to sustainability, economy and social well-being. The ability to gather and interpret relevant information;
8. The ability to maintain and extend one's competences by permanent self study, with a high degree of autonomy.

An overview of specified intended learning outcomes of the Bachelor's programme is provided in Appendix 3.

A graduate of the Delft *Mechanical Engineering Master's programme* has:

1. Competence in one or more scientific disciplines;
2. Competence in conducting research;
3. Competence in designing;
4. A scientific approach (including life-long learning);
5. Basic intellectual skills;
6. Competence in cooperating and communicating;
7. Consideration of the temporal and social context including sustainability.

Specified intended learning outcomes of the Master's programme are included in Appendix 3 of this report.

Various tracks have their own specific requirements:

- Most Biomechanical Design graduates, through their Master's projects and in close collaboration with researchers at the TUD, will have written a scientific paper with the view to be published in an academic journal or conference proceedings.
- In addition to the qualification common to all students of the ME Master, students of the Precision and Microsystems Engineering track will acquire an understanding of the fundamental concepts of physics, related specifically to micro and nano devices, and to advanced mechatronic systems.
- Graduates from the Solid and Fluid Mechanics track have developed themselves into researchers, who are continuously driven by 'why' and 'how', rather than by the 'how much'-questions, and they have further developed this quality during both years of the

programme especially when they work in projects or on assignments in close contact with academic staff and PhD-students.

- Transport Engineering graduates have acquired a thorough understanding of theory and practical experience with transport systems through industrial collaboration. They have an orientation on world-wide developments that put an increasing demand on capacities of transport networks and systems.

The committee has studied the intended learning outcomes of the Bachelor's and the Master's programme as provided in Appendix 3 and established that these are very well defined. Intended learning outcomes have been specified for each track in the master's programme. The learning outcomes are clear and specific. They indicate in a transparent way the intended level and orientation of the programmes and the requirements the students have to meet for graduation.

Considerations

The committee concludes that the Bachelor's and the Master's programme Mechanical Engineering of the TU Delft both have strong ambitions and internationally well known profiles. The international standards for the Bachelor's and Master's level are reflected in the intended learning outcomes, both in general terms and for the domain of Mechanical Engineering (ABET, OECD, ASME). The intended learning outcomes are transparent and specific and in line with the ambitions of the programmes. The Bachelor's and the Master's programme, therefore, meet the criteria for standard 1 of the assessment framework.

The committee was, however, not convinced of the added value of the added value of the number of tracks and specialisations within the Master's programme. The committee suggests reconsidering this track structure, without losing the advantages of diversity in the programme.

Conclusion

Bachelor's programme Mechanical Engineering: the committee assesses Standard 1 **good.**
Master's programme Mechanical Engineering: the committee assesses Standard 1 **good.**

Standard 2: Teaching-learning environment

The curriculum, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes.

Explanation:
The contents and structure of the curriculum enable the students admitted to achieve the intended learning outcomes. The quality of the staff and of the programme-specific services and facilities is essential to that end. Curriculum, staff, services and facilities constitute a coherent teaching-learning environment for the students.

Findings

The following aspects will be discussed in this section: the structure of the curriculum (2.1.), didactic principles (2.2.), feasibility (2.3.), staff (2.4.), programme-specific facilities (2.5.) and programme-specific quality assurance including the improvement measures that have been made in response to the previous evaluation (2.6.).

2.1. Structure of the curriculum

The *Bachelor's programme Mechanical Engineering* consists of a major in Mechanical Engineering (150 EC), which is equal and compulsory for all students, and a minor (30 EC) as elective part scheduled at the beginning of the 3rd year. An overview of the Bachelor's curriculum is included in Appendix 4.

The courses have been grouped into five clusters:

Mathematics cluster - This cluster contains the courses Analysis, Linear Algebra, Differential Equations, and Probability & Statistics, and the courses on Simulation and Programming (Delphi, Matlab and Ansys), and Electrical Drives. In addition, some courses also include exercises from the application of Matlab and Ansys to further improve skills in simulation and programming.

Physics cluster - This cluster contains the courses Statics, Strength, Materials Science, Thermodynamics, Dynamics, Fluid Mechanics and Non-linear Mechanics.

Mechanical Engineering cluster - This cluster contains the courses Manufacturing, Design of Mechanical Systems, Modelling and Control, Signal Analysis, Process Technology, Microsystems and Evolving Design.

Projects cluster - This cluster contains the projects on Design (Analysis, Synthesis and Realisation), Mechatronics, Process & Energy, and Research.

Economics, Society & Social Skills cluster - This cluster contains courses on presentation, reporting and project management skills, research methodology, business economics as well as on the societal subjects safety, ethics and sustainability.

The first year contains large mathematics and physics parts, as a foundation for the following courses and as a selection tool for the following years of the Bachelor's programme. It also consists, to a large extent, of projects. In these projects earlier taught knowledge is applied. The second year goes deeper into the mathematical and physical foundations and into the diverse parts of mechanical engineering, such as mechatronics, fluid dynamics, material science, and simulation tools. The first semester of the third year contains the minor. The second semester mainly contains mechanical engineering courses and a course on economy alongside with the final Bachelor's project, which consists of a group-research assignment with a report and a public defence.

The minor is a coherent package of subjects forming a kind of mini-degree programme in itself and is finished with a project. The space allotted to the minor can also be used to meet a student's individual wishes, e.g. to switch to a different Master's programme or acquire international and/or working experience. It is also possible to compile a free choice minor. The Board of Examiners decides whether the proposed minor programme is coherent and whether it has a sufficient academic level. In principle, students can take minors at any university, both at home and abroad. However, most students take a minor offered by TU Delft. TU Delft offers approximately 50 thematic minors each year. The quality of the minors offered by TU Delft is guaranteed by a TU-wide central review committee.

Since 2010 the TU Delft has a so called Challent (Challenge the Talent) Programme for Bachelor students who perform very well, to challenge them by doing an additional programme. In 2008 the Faculty 3mE took the initiative to start with a similar programme called TopTrack. TopTrack is accessible to the top best 5-10% of the second and third year Mechanical Engineering and Marine Technology students. Since 2012 these programmes are transmitted into the Honours Programme Delft. The goal of these programmes is to offer excellent students the opportunity to learn more than just their curriculum. Extra classes, assignments and projects with industry are options, while they can also tailor their own minor, going much further and deeper into the topic than the commonly offered minors can do.

There are several learning lines in the Bachelor's programme:

- Mathematics, with a broad basis in the first year and more specialist courses in the second year.
- Statics, Dynamics and Nonlinear Mechanics in the first two years.
- Thermodynamics in the first two years, followed by Fluid Dynamics and Heat and Mass Transfer, including a large project on an energy-conversion system.
- Material Science and Strength Theory in the first two years.
- Process Technology in the second and third year.
- Modelling, Control and Signal Analysis in all three years, including a large mechatronics project in the second year.

The learning lines cover all three years ensuring a logical increment of study contents and a build-up of knowledge and competences during the course years. The structure of these learning lines in combination with two educational forms, course based education and projects, ensure that both knowledge and application skills are increased during the course of the programme.

Although the learning lines give a clear structure to the programme, the students experience the programme as fragmented. This observation was confirmed by the students the committee interviewed during the site visit. The Bachelor's curriculum contains too many small courses. Some of the students mentioned that the curriculum is too diverse. However others appreciated this diversity resulting from the number of subjects covered in the curriculum, since almost all students will find topics of their interests in the programme. The small courses also add to the feeling of the students that the programme is overloaded. The committee agrees with the students that although the diversity in the programme is appreciated, the structure could be improved by scheduling less and bigger courses.
Management told the committee that the programme is under reconstruction. In September 2013, courses will be clustered into larger modules, resulting in less examinations and more cohesion in the programme. The committee appreciates this restructuring.

The basic structure of the *Master's programme* is similar for all seven tracks mentioned in Standard 1. They all have a nominal study length of two years, equivalent to 120 EC. The tracks are composed of a first year with compulsory core courses, a specialisation part and elective courses, which the student has to choose in consultation with one of the track coordinators or his mentor. Elective courses provide students with the opportunity to deepen or broaden their knowledge. This part of their individual study programme (ISP) is dealt with in close consultation with their graduation professor and the track-coordinator. They also make sure that the students' electives contribute to the coherence of the total course package.

The second course year for all tracks is a 60 EC research programme, made up of three parts:

- An education block of 15 EC that may consist of courses, a research project or an internship (when the Master's thesis project does not contain an internship);
- A literature study (10-15 EC) that is concluded with a report, a presentation, or a discussion;
- And finally the graduation (Master thesis) project (30-35 EC), also rounded off with a report, a presentation (in some tracks including a formal interim report) and a discussion during the final exam.

An overview of the Master's curriculum is given in Appendix 4.

The internship provides the students with the opportunity to gain first-hand experience in the domains of their choice and it confronts them with setbacks as they could experience in later professional life and intellectual level which is expected after their graduation. During the internships students have to show that they are capable of applying the knowledge, skills and attitude that has been acquired in the first Master's year. Sometimes the internship is combined with the graduation project, for instance when students perform their graduation project within a particular institution or company. The graduation project could also be at the Faculty 3mE or elsewhere at Delft University, often related to the research of a PhD-student, who would be the daily supervisor. The graduation project is an individual research project.

The committee noticed that the size of the different 'parts' in the tracks as well as the resulting products vary considerably. This does not contribute to a transparent overview of the Master's programme the Faculty 3mE of TU Delft offers. Management is aware of this fact and assured the committee that it is working towards more uniformity.
Students are positive about the internships and confirm that they form a valuable part of their education. It is not difficult to find an internship position, industries are eager to accept students from the TU Delft.

2.2. Didactic principles

The *Bachelor's programme* has two principal forms:

- Course-based education, i.e. lectures/workshops ('colleges/instructies') with associated examinations. The lectures are primarily used to teach the basic fundamental knowledge and some applications.
- Projects in which students work together in project groups. Projects are primarily used to apply the earlier taught knowledge in a realistic setting. Next to that, projects include design and non-technical subjects (e.g. project skills, communication, sustainability, safety and ethics). Most projects are multi-disciplinary and are defined by a group of teachers. Each project has one teacher who has the final responsibility ('docent-opdrachtgever'; teacher-commissioner). During projects lectures are given by the teachers to elucidate the goals of the project. Regular project-group meetings are scheduled, during which a teacher (second and third course year) or student-coach (first course year) gives guidance to the project group with regard to the planning, team work and approach of the project. Projects very much contribute to the motivation of students, which is confirmed by evaluations.

Course-based teaching (lectures with an examination for every course, and sometimes assignments) is used for fundamental engineering (mathematics, solid and fluid mechanics, control engineering, thermodynamics, physical transport phenomena, materials science) and for domain-specific knowledge (design of mechanical systems, production, process technology, micro technology). For each course, it is essential that the theory is well understood and can be applied. Assignments contribute towards understanding the theory.

The second teaching method concerns projects. This method is used to apply the knowledge that has been taught in the course-based lessons. Projects involve teamwork, individual tasks and some course-based teaching. Lectures are used within projects to introduce new material or to clarify project related tasks. The first-year projects are built up around design tasks. At the end of the first year, students do an individual internship in industry. This provides them with the opportunity to become familiar with the culture of the working environment and with actual examples of mechanical engineering. The internship is also intended to help these future engineers become acquainted with communicating with technicians. In the second year, the projects focus on a thermodynamic system (one semester) and a mechatronic system (one semester). The first semester of the third year is taken up by the minor programme. The minor programmes provided by the Faculty of 3mE all include projects that are largely design-based.

The Bachelor's Research Project in the second semester of the third year, the final part of the Bachelor's programme, is a 9 EC group project that concerns an original research question. A great deal of the knowledge that has been acquired in the earlier courses is needed for this research subject. The project follows the lines of the lecture Research Methodology, which is taught simultaneously. A congress is organised on the final day of the curriculum at which the results of the research carried out in the Bachelor's project are presented to fellow students, a scientific jury and the public. The committee appreciates the structure of this final Bachelor's project. It gives the students the possibility to practice their skills, to apply their knowledge and to show what they have learned. The programme manager has managed to find a form to accommodate a large number of students without giving in on quality and quality assurance.

The programmes of the seven engineering tracks in the *Master's programme* have two important phases: the first year when the focus is on knowledge absorption and the second course year during which the absorbed knowledge and skills are applied. The (domain-specific) knowledge is conveyed in three different ways. In the first course year the transfer takes place during the core courses, specialisation courses and elective courses in the form of lectures, given simultaneously to all students. In a number of cases lectures are combined with instructions or small specific projects to illustrate and/or to apply the acquired theoretical knowledge.

Laboratory courses, assignments and projects play an important role in the acquisition of hands-on experience, skills, attitude and the setup of labs, while at the same time students are already applying some of the recently acquired knowledge too. Another important factor in this educational process is the teaching staff themselves, as they serve as guides and as a source of inspiration for the students.

The second year may be regarded as a compilation of three assignments, to be carried out individually: the literature search, the internship and the graduation project. During the second year the student has a graduation professor and usually additionally a daily supervisor as coach. The internship provides the student with the opportunity to have first-hand experience in the domain of his choice and it confronts him with – as mentioned earlier – setbacks and the intellectual level that is expected of him after graduation.

The committee finds the described modes of instruction and teaching in the programmes appropriate. The projects scheduled in every bachelor year are a good means to help the student integrate and apply the knowledge acquired in the courses; according to the committee the teaching forms in the Master's programme are adequate, but not innovative.

2.3. Feasibility

The curriculum is designed for students, who have obtained a VWO (pre-university education) diploma either of the track 'natuur en techniek' (nature and technology) or 'natuur en gezondheid' (nature and health; including Mathematics B and Physics) track. The contents of the mathematics and physics courses are in line with VWO final qualifications.
A problem with the VWO student intake is that they do not always have the knowledge and skills that they should have according to the VWO final qualifications. To make incoming students aware of this problem, they have to take a mathematics test in their second university week. They have to succeed for this test in order to be allowed to take the Analysis 1 examination. The result of the test can be used by students to refresh their knowledge.

During information meetings the marketing staff, student counsellors, lecturers and students inform the potential students about the formal requirements to enrol. It is also mentioned that for a successful study, it is required to have a real interest in the subject of the study, to be prepared to invest sufficient time in the study and that reasonably good marks for mathematics and physics VWO are important. The programme has seen an increase in the number of students. While on average about 20% drop out during their first year up to 2009, the total drop out rate amounts to about 35%. In 2009 the BSA (Binding Recommendation on Continuation of Studies) has been introduced. It is expected that due to the introduction of the BSA the drop-out in the Bachelor's programme is shifted largely to the first year. In recent years actions have been taken to improve the success rate of students. This includes emphasising that more effort is required of the students than in their pre-university education and that change is required of the old 'If I don't pass this year, there will be another chance next year' culture among students. For this purpose, the BSA is a powerful tool.

The students report to the committee that they have to work hard to keep up with the pace of the Bachelor's programme, an attitude they were not used to during their VWO education. They confirm that the programme gives sufficient information about the heavy study load and the necessity to study regularly. Another obstacle for study progress is the low level of mathematics knowledge of first year students, although this seemed to have improved the last years. The first evaluation of the introduction of an entry exam for Mathematics is positive. Students however also report study delay caused by the project, e.g. when experiments fail. The committee would suggest the supervisors of these projects to make sure that students learn to work with deadlines and inform them that a lot can be learnt from failing experiments.

The influx of students per *Master's programme* track and over time varies significantly. In the past, regulations allowed both students in the final stage of their Bachelor's programme and students from universities of applied science participating in a bridging programme, to follow Master's courses. As a result it is not possible to determine an exact time of enrolment in the Master's programme for these students and a fair evaluation of the actual study duration for the Master programme cannot be provided.

The nominal period for the Master programme is 24 months. Only students coming from outside the European Union comply with the set period. The reasons for this is that foreign students enrol at the start of the Master programme, which means that the date of registration is very clear, as is the date of graduation. Moreover, these international student also have other reasons (monetary, visa) to finish within the nominal time. For graduates from the

3mE's Bachelor's programme it is often difficult to determine when they commenced the Master programme. Many of them participate in master's courses (long) before they have passed their bachelor's graduation. The Bachelor-before-Master rule (*Harde Knip*), introduced in September 2010 is already putting an end to this. Students have to complete their Bachelor's programme before they are permitted to commence the Master's programme.

2.4. Staff

3mE lecturers teach in both Bachelor's programmes (Mechanical Engineering and Marine Technology) and the six Master's programmes offered by the Faculty. The majority of the teaching staff has completed a PhD, although the committee is of the opinion that some improvement can still be made here. All teaching staff is actively involved in research. The committee appreciates that a number of staff members has been working in industry and/or at a research institute. Some of them combine their job in industry with their position at the university.

The teaching qualities of new employees are the starting point in the appointment process. Teaching qualities form part of the annual review in the R&D staff evaluation cycle. The Basic Teaching Qualification programme (BTQ) has to be taken as a whole or as a set of tailor-made courses by present teaching staff with no teaching experience. Lecturers who need to improve in certain areas, indicated by results of evaluations, or because of specific wishes or agreements with their manager, are given targeted training. Newly appointed lecturers must have obtained their BTQ within two years.

Due to the increased student inflow in the Mechanical Engineering programmes there is a high teaching load for the staff involved. The committee however thinks that the academic staff of the Faculty is at an appropriate level, quantitatively as well as qualitatively. The committee appreciates that the Faculty 3mE is actively encouraging teachers to improve their teaching skills. The committee is also positive about the number of teachers that has experience in industry.

2.5. Programme specific facilities

During the site visit the committee visited the college rooms, the laboratory facilities for teaching and the self-study rooms for the students in the buildings of the Faculty 3mE. The committee was impressed by the creativity of the management to find solutions for the large numbers of students it has to accommodate. All physical spaces are used in a most efficient way to create room for the students for self study and to co-operate in the projects.

The Measurement Shop has been realised in 2007 for facilitating research for projects (including student projects), laboratory courses, and classes. It provides support for a large laboratory room as well. This is used for instance for the second-year Mechatronics project. The Shop has measurement equipment that can be borrowed for experiments. It also offers expertise for experiments and in carrying out measurements. The laboratory room makes use of the most up-to-date developments in the field of ICT. Students can use their own laptops. Teachers can be seen from every workplace thanks to the use of several wide-screen monitors. Every laboratory table has measuring equipment and a computer system, and the teacher has an interactive beamer screen at his disposal.

The introduction of Collegerama for the lectures in the Bachelor's programmes started in 2007-2008. Most of the Bachelor lectures are recorded and are available as video images to view online, including any related slides (PowerPoint).

A walk-in workshop is available for practical exercises in processing techniques (first year projects) and for the construction of designs for the design competition in the first year. The workshop contains lathes, milling machines, drills, sheet metal machines, welding machines, laser cutting, CNC lathes and a 3D printer. Students are given instructions with regard to safety and on how to use the equipment before they are permitted to work in the workshop. In addition to this students can use the assembly basement for elementary activities.
For instruction purposes also external facilities are available, e.g. the 'Leidse Instrumentmakersschool' in Leiden, the 'RDM-campus' in Rotterdam and the 'Leonardo Experience' in Dordrecht.

Within the Education and Students Affairs Department (O&S) of 3mE both the Student Counsellors as well as the staff of the International Office play an active part in advising and coaching students. In June 2012 a survey was carried out among all 3mE students to analyse the appreciation as well as the needs with respect to the support offered by O&S.

Student Counsellors are focused on students and their problems. This can result in a role in which the Student Counsellor acts as the student's representative towards teaching staff. In the first part of the course year 2012 a survey among lecturers and Student Counsellors is planned to analyse the relationship between them and to investigate whether or not measures for improvement of co-operation have to be taken. Study Counsellors are also involved in the monitoring of the study progress of the students as well as the amount of time students spend on their Bachelor's projects in close contact with the direct supervisor.

In the Master's programme academic counselling is in place to advise and support students with respect to all possible difficulties that might occur during their studies that are directly study related. In the case of problems not directly related to the Master's programme, the university has student psychologists and student counselling services. Students are supported in their choices by their master/track coordinator. Care is taken that their course programme is coherent as well as in line with their personal ambitions. In consultation with the coordinator the students set up a course package and are encouraged to visit the coordinator when further advice is needed, or when the course package needs to be readjusted.

2.6. Programme-specific quality assurance

Feedback from students, as part of the regular quality-assurance process, on both the programme and the individual courses, is obtained each educational period by means of on-line surveys and evaluation sessions. The results are discussed in the Education Committee (OCWB) and improvements are implemented. The committee met representatives of the Education Committee and could establish that it is working adequately. The students reported to the committee that evaluation results are in fact discussed in the Education Committee and that several of the reported issues resulted in changes and improvements in the programme. They also mentioned that many teachers have a personal response group and are continuously trying to improve themselves. Teachers can easily be approached by e-mail to make an appointment.

The programmes provided a list of actions taken as a result of the assessment in 2006. Several actions resulted in improvements. The major concerns of the assessment committee in 2006 with regard to the bachelor programme were do-ability and study load, and student intake. The self evaluation report describes several actions aiming at stimulating the student's planning, which are according to the committee valuable. However, considering the cumulative bachelor yield as presented in Appendix 5, the success of these actions is not yet visible. Major improvement is the introduction of the 'Bachelor-before- Master' (harde knip).

The results of 'de harde knip' will become available in the next years. Improvements concerning student intake are still in the phase of proposals, but promising.

The previous assessment committee already found the large variety of Master tracks offered less desirable, this fact remains an issue for this assessment committee. However improvements have been made with regard to a uniform vision on the structure of Master tracks.

Considerations
The committee has investigated the different aspects of the teaching-learning environment to assess whether the intended learning objectives can be achieved. The meetings with students, staff and the educational committee gave clear information about the level and orientation of the Bachelor's and Master's programmes.

The Bachelor's programme provides the necessary foundation in theory and skills. The contents and structure of the curriculum enable the students admitted to achieve the intended learning outcomes. The committee has learned that the programme management is working on restructuring the Bachelor's curriculum to make it less fragmented than is now experienced by students. The new Bachelor's curriculum will contain less small courses and more integrated modules. The Master's programme is well structured and enables the students to do an internship as well as a considerable research project. As stated the committee was not convinced of the added value of defining seven tracks, further subdivided into 17 specialisations within the Master's programme. Some of the tracks are strongly related to other Master's programmes. For example, there is a large overlap between the elaborate final qualifications of the track Materials Engineering and Applications and the Master's programme in Materials Science and Engineering. The committee suggests reconsidering this track structure, without losing the advantages of diversity in the programme.

The described modes of instruction and teaching in the programmes are appropriate. The projects scheduled in every bachelor year are a good means to help the student integrate and apply the knowledge acquired in the courses. According to the committee the teaching forms in the Master's programme are adequate, but not innovative.

Due to the high student inflow in the Mechanical engineering programmes there is a high teaching load for the involved staff. The committee however thinks that the academic staff of the Faculty is at an appropriate level, quantitatively and qualitatively. The committee appreciates that the Faculty 3mE is actively encouraging teachers to improve their teaching skills. The committee is also positive about the number of teachers that has experience in industry.

The facilities are adequate. The committee highly appreciates the creative way in which the programme management improves the study facilities with the limited means it has and the increasing student numbers.

The average length of study remains a concern. The feasibility of the programme is in order, even though only a small minority of the students finishes on time. The students indicate that they often give priority to other activities, such as the student association, sports, study trips or jobs. The committee expects that new measures such as BSA and 'harde knip' will lead to different study behaviour. In addition, the committee advises to emphasise to staff and students that 'good' is 'good enough' and that finishing a project on time is also an important learning objective.

Conclusion
Bachelor's programme Mechanical Engineering: the committee assesses Standard 2 as **satisfactory.**
Master's programme Mechanical Engineering: the committee assesses Standard 2 as **satisfactory.**

Standard 3: Assessment and achieved learning outcomes

The programme has an adequate assessment system in place and demonstrates that the intended learning outcomes are achieved.

Explanation:
The level achieved is demonstrated by interim and final tests, final projects and the performance of graduates in actual practice or in post-graduate programmes. The tests and assessments are valid, reliable and transparent to the students.

3.1. Findings

This section consists of two parts. First, it deals with the committee's findings with regard to the system of assessment (3.1.). Secondly, it answers the question of whether students achieve the intended learning outcomes (3.2.).

3.1. Assessment system

For each course in the curriculum the study results of the students are evaluated by one or more tests. Regular courses are tested by a written examination directly at the end of the teaching period. In case students fail a test, a resit is possible at the end of the next teaching period or in the August resit period. For each course two test possibilities are given per study year. For some courses voluntary exercises can be worked out during the teaching period that may give a bonus to the results of the formal test. For a few courses participation in exercises during the teaching period is an entry requirement for the first-following examination. The formula to determine the final mark based on the marks for examination, exercises and voluntary tests, is published on the Blackboard site of that course.

Projects are evaluated based on a project report and/or a presentation. In the *Bachelor's programme* the report and presentation are the responsibility of the complete project group. Each student in the group receives the same mark. On top of this, each student's contribution to the project is evaluated. This evaluation is done by the coach of the project group (propaedeutic year) or the teachers responsible for the project. The Bachelor's Research Project is the final project of the Bachelor's programme. Students carry out small-scale-scientific research projects in groups of four students. The project is rounded off with a mini paper and a one-day symposium. The projects are assessed on basis of the mini-paper, the presentation at the symposium and the defence. Furthermore the supervisor of the project provides an assessment of the research file and the learning process of the students. The final grade for the project-work is therefore an average of five assessments.

An element of course-based education during the first Master's year is that the students complete each of their courses by an exam, whether they are core courses, specialisation courses or elective courses. At some tracks this may include exercises and project work designed to train students in practical application, while other tracks include homework assignments and individual or group project work as well.

The Faculty 3mE has one *Board of Examiners* which is responsible for all degree programmes offered. It is responsible for the pass/fail rules for the Propaedeutic and Bachelor examinations, as well as the criteria for a degree with distinction (cum laude). This Board also sets the rules and guidelines for tests. The pass/fail rules for each type of courses/subjects of the different programmes are published in the study guide.
The Board determines ten times per study year which students have passed and failed for the Bachelor and the Master examinations. The pass/fail rules are then applied. In special cases the Board may deviate from these rules but always in favour of the student. For each course the testing method is determined by the responsible teacher of that course in consultation with the Director of Education and/or the Education Advisor.

The Board of Examiners delegates certain clearly defined duties. The most important of them is the Master's graduation project, which is delegated to a professor as chairman, at least one member from the scientific staff of the research group responsible for the specialisation and at least one member from the scientific staff of a different research group of Delft University of Technology. The students' internship reports and presentations are evaluated and graded by a combination of a supervisor from the institute or the company, a staff member of the laboratory of the specialisation (or whatever is applicable for the individual situation) or by the track-coordinator. There is a special form for the final examination that has to be used to assess all aspects of the examination. As this form is quite extensive, some groups use shorter forms. A form should evaluate at least four aspects:

- The graduation process and the attitude towards the work during the MSc project;
- The quality of the Master thesis;
- The quality of the presentation;
- And the quality of the defence.

Usually, the presentation takes thirty minutes and the defence one hour. The evaluation forms of the MSc examinations are collected and archived by the secretariats of the departments.

The committee had a meeting with the Board of Examiners and established that the Board is in control of the rules and the procedures for exams. The committee has noted that the Board is aware of the recent extension of its responsibilities and that it is in the process of developing and implementing policies and plans in regard to testing and exams 'the New Delft Test Methodology'. The committee noticed that a variety of forms were still used for the assessment of master's graduation projects. The board of Examiners assured the committee that it has taken action to bring more uniformity in the forms and the way the forms are used.

3.2. Achievement of intended learning outcomes
During the site visit all bachelor examinations including the students' answers were available for inspection by the committee. They were found to be at an adequate level and well-marked.

The committee has studied a selection of twelve Bachelor's graduation projects and eight Master's theses to assess if the intended learning outcomes are achieved.

The committee concludes that all Bachelor's papers meet the requirements. The committee appreciates the way the 'mini-paper' is structured as a scientific paper.

The Master's theses the committee has studied were also adequately assessed. The Master's theses indicate that the graduates actually have achieved a level that is better than what can 'just be expected' in a master's degree programme. Graduates of the Mechanical Engineering programme of the TU Delft very easily find employment in the international field of industry and academia. The level that is achieved by the graduates of the programme is generally seen as very high.

Considerations
The committee has looked into the assessment system and the Bachelor's and Master's theses in order to answer the question if the intended learning outcomes are achieved. The committee is convinced that the assessment system is sufficiently valid and reliable. The committee has seen that the Board of Examiners has made a start with the implementation of a clear and updated, adapted to renewed legislation, test policy and achieving uniformity of the Master's theses assessment forms.

The level of the theses is higher than the required level of an academic Bachelor's and Master's programme. Bachelor's graduates are well prepared to continue their studies in an academic Master's programme and Master's graduates have an excellent foundation for a career in industry as well as in research. The level of the graduate TU Delft mechanical engineers is generally acknowledged as very good to excellent.

Conclusion
Bachelor's programme Mechanical Engineering: the committee assesses Standard 3 as **satisfactory.**
Master's programme Mechanical Engineering: the committee assesses Standard 3 as **good.**

General conclusion

The committee concludes that Bachelor's and Master's programmes Mechanical Engineering meet the requirements for accreditation. The intended learning outcomes of the Bachelor's and the Master's programme Mechanical Engineering are formulated in line with the domain-specific framework and the requirements for an academic Bachelor's respectively Master's programme. The curricula enable the students to achieve the intended learning outcomes. The programmes have an adequate assessment system level and the level of the graduates is very good.

Conclusion
The committee assesses the *bachelor's programme Mechanical Engineering* as **satisfactory.**
The committee assesses the *master's programme Mechanical Engineering* as **good.**

Appendices

Appendix 1: Curricula Vitae of the members of the assessment committee

Joris De Schutter (chair) received the M.Sc. degree in mechanical engineering from the Katholieke Universiteit Leuven, Belgium, in 1980, the M.Sc. degree from the Massachusetts Institute of Technology, in 1981, and the Ph.D. degree in mechanical engineering, also from KU Leuven, in 1986. Following work as a control systems engineer in industry, in 1986, he became a lecturer in the Department of Mechanical Engineering, KU Leuven, where he has been a full professor since 1995. He teaches courses in kinematics and dynamics of machinery, control, robotics and optimization. His research interests include sensor-based robot control and programming, optimal motion control of mechatronic systems, and modeling and simulation of human motion. In 2000-2001 he spent a sabbatical year in industry (environmental technology). From 2001 to 2003 he was president of K VIV, the Flemish association of university-graduated engineers.

Gijs Calis received his master's degree in Mechanical Engineering (Production Automation) from Eindhoven University of Technology in 1974. He held various management positions within the Stork group of companies as of 1974. His latest position was Corporate Director Risk Management, Stork B.V.; Corporate Head Office (2002 – 2010).
He retired in April 2010. His current other positions include being the chairman of the Division of Mechanical Engineers of the Royal Institute of Engineers in The Netherlands; vice-chairman and arbitrator of the Council of Arbitration for the Metal Trade and Industry; and chairman of the Policy Committee 'Machinebouw' of NEN, the standardisation institute of the Netherlands. Formerly he was a member of the Advisory Board of the Graduate School of Engineering Mechanics in the Netherlands (1996 -2011) and a member of the Advisory Committee to the Faculty of Mechanical Engineering of Delft University of Technology (1996 - 2000) and the UHD committee of this Faculty (2000 – 2005).

Hetty Grunefeld has a master's degree in Computer Science from the University of Twente (1988). Since then she worked as a teacher and as educational consultant within the Faculty of Computer Science on several curriculum development and quality enhancement projects. In 1995 she started working within the Educational Centre on similar projects in e.g. Mechanical Engineering. Since 2001 she has been working as an educational development consultant at Utrecht University. She is involved in curriculum development projects and quality enhancement. She is programme leader of the prestigious course Educational Leadership that was developed by Utrecht University. She was a member of the assessment committee that evaluated the quality of the Electrical Engineering programmes (HBO, 1995) and of the committee for Economics (WO, 2009).

Elze Porte is master student Mechanical Engineering of the University Twente. She did her bachelor programme Mechanical Engineering in Twente and a minor at the Technical University in Vienna. She has been a member of the educational committee since 2010 and a member of the committee for the restructuring of the mechanical engineering programmes since 2011. In 2011 and 2012 she has been a student assistant for the Calculus 3 course.

Paul van Houtte is professor at the Department of Metallurgy and Materials Engineering of the Katholieke Universiteit Leuven, Belgium. He did his Master of Science in Mechanical Engineering in 1970 at the Faculty of Engineering of the "Katholieke Universiteit Leuven", Belgium and his Ph. D in 1975, directed by Prof. Etienne Aernoudt, of the Department of Metallurgy of the Katholieke Universiteit Leuven were Van Houtte remained during his career. From 1975 -1977: research associate (temporary position), 1977-1988: permanent position as assistant (several ranks), 1988-present: permanent position as professor (several ranks); from 1995: Full Professor. He has been member and chair of several committees among which member of the evaluation commission of the Faculty of Engineering.

Marc Vantorre obtained his degree of naval architect (MSc) in 1981 and PhD titles in 1986 and 1990, all at Ghent University. Presently he holds the position of senior full professor at Ghent University (Faculty of Engineering and Architecture), where he is head of the Maritime Technology Division. He is responsible for the courses in maritime hydrostatics and hydrodynamics for students Master of Electromechanical Engineering (main subject Maritime Engineering). He also teaches courses Ship Technology and Water & Shipping on behalf of the interuniversity (UGent - UA) programmes Master of Maritime Science and Advanced Master Technology for Integrated Water Management, respectively. He is member of the Programme Committees of the mentioned master programmes. His research activities concern ship behaviour in shallow and restricted waters, including maneuvering and vertical motions induced by waves and squat, as well as wave energy conversion. The research on the first topic is mainly performed in close co-operation with Flanders Hydraulics Research (Antwerp, Flemish Government). He is and has been member of several international working groups (PIANC, ITTC).

Appendix 2: Domain-specific framework of reference

This appendix gives a brief summary of the ABET definitions of Mechanical Engineering added by a summary of the OECD and ASME definitions.

1. ABET

Engineering
The American Engineers' Council for Professional Development has defined engineering as: The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property. We used the accreditation criteria of the Accreditation Board for Engineering and Technology (ABET) as a domain-specific qualifications framework to formulate the objectives and outcomes of the programme.

Mechanical engineering
Mechanical engineering is a diverse subject that derives its breadth from the need to design and manufacture everything from small individual parts and to large systems. Mechanical engineering is a discipline of engineering that applies the principles of physics and materials science for analysis, design, manufacturing, and maintenance of mechanical systems. It is the branch of engineering that involves the production and usage of heat and mechanical power for the design, production, and operation of machines and tools.
The fundamental subjects of mechanical engineering include:

- Statics and dynamics
- Strength of materials and solid mechanics
- Instrumentation and measurement
- Thermodynamics, heat transfer, energy conversion, and HVAC
- Combustion, automotive engines, fuels
- Fluid mechanics and fluid dynamics
- Mechanism design (including kinematics and dynamics)
- Manufacturing engineering, technology, or processes
- Hydraulics and pneumatics
- Mathematics – in particular, calculus, differential equations, and linear algebra
- Engineering design
- Product design
- Control theory and mechatronics
- Material engineering
- Design engineering, computer-aided design (CAD), and computer-aided manufacturing (CAM).

Incoming students
We request that all incoming students have a Bachelor's degree. The ABET document 'Criteria for Accrediting Engineering Programmes'3 describes the following student outcomes for baccalaureate level engineering and engineering technology programmes:
a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyse and interpret data

c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multidisciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

General criteria for Masters level Engineering programme
The ABET document 'Criteria for Accrediting Engineering Programmes' gives the following two general criteria for Masters level programmes:
Masters level programmes must develop, publish, and periodically review, educational objectives and student outcomes. The criteria for Master's level programmes are fulfilment of the baccalaureate level general criteria, fulfilment of programme criteria appropriate to the Master's level specialisation area, and one academic year of study beyond the baccalaureate level. The programme must demonstrate that graduates have an ability to apply Master's level knowledge in a specialized area of engineering related to the programme area.
Each programme must satisfy applicable Programme Criteria (if any). Programme Criteria provide the specificity needed for interpretation of the baccalaureate level criteria as applicable to a given discipline. Requirements stipulated in the Programme Criteria are limited to the areas of curricular topics and faculty qualifications. If a programme by virtue of its title, becomes subject to two or more sets of Programme Criteria, then that programme must satisfy each set of Programme Criteria; however, overlapping requirements need to be satisfied only once.

General criteria for Mechanical Engineering programme
The ABET document also gives the following two programme criteria for Masters level Mechanical Engineering:
1. Curriculum
The curriculum must require students to apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations); to model, analyse, design, and realize physical systems, components or processes; and prepare students to work professionally in both thermal and mechanical systems areas.
2. Faculty
The programme must demonstrate that faculty members responsible for the upper-level professional programme are maintaining currency in their specialty area.

2. OECD

The OECD offers a test, Assessment of Higher Education Learning Outcomes (AHELO), to assess Learning Outcomes on an international scale by creating measures that would be valid for all cultures and languages. It can be compared with the PISA-test for undergraduate education. AHELO gives several definitions of engineering, the following two describe the vision of the faculty 3mE very well:

- Professional engineering is not just a job it is a mind set and sometimes a way of life. Engineers use their judgment and experience to solve problems when the limits of scientific knowledge or mathematics are evident. Their constant intent is to limit or eliminate risk. Their most successful creations recognize human fallibility. Complexity is a constant companion.

and

- Engineering is a profoundly creative process. A most elegant description is that engineering is about design under constraints. The engineer designs devices, components, subsystems, and systems and to create a successful design, in the sense that it leads directly or indirectly to an improvement in our quality of life, must work within constraints provided by technical, economic, business, political, social, and ethical issues.

Furthermore, AHELO stresses that 'The members of the engineering profession are expected to exhibit the highest standards of honesty and integrity' and also the importance of good ethical behaviour which is strongly endorsed by the Delft University of Technology.

Specific learning outcomes for Mechanical Engineering according to OECD AHELO are:

1. The ability to demonstrate knowledge and understanding of the basics of
   a. mathematics including differential and integral calculus, linear algebra, and numerical methods
   b. high-level programming
   c. solid and fluid mechanics
   d. material science and strength of materials
   e. thermal science: thermodynamics and heat transfer
   f. operation of common machines: pumps, ventilators, turbines, and engines
2. The ability to perform analysis of
   a. mass and energy balances, and efficiency of systems
   b. hydraulic and pneumatic systems
   c. machine elements
3. The ability to carry out the design of elements of machines and mechanical systems using computer-aided design tools
4. The ability to select and use control and production systems.

3. ASME

Trends for the future of mechanical engineering

The Institute for Alternatives Futures describes in an environmental scan for ASME and the Global Summit on the Future of Engineering mentions nine trends that will change the character of mechanical engineering in the coming decades. These nine trends play an important role in the development of our curriculum.

1. Developing Sustainably: Rapidly developing economies are adding to global environmental competition for energy, water, and other high-demand resources. Mechanical engineering will be challenged to develop new technologies and techniques that support economic growth and promote sustainability.
2. Engineering Large & Small Scale Systems: Engineers in the future will work at the extremes of very large and very small systems that require greater knowledge and coordination of multidisciplinary and multi-scale engineering across greater distances and timeframes.
3. Competitive Edge of Knowledge: In the next decades, the ability of individuals and organisations to learn, innovate, adopt and adapt faster will drive advanced economies.

Mechanical engineering education will be restructured to resolve the demands for many individuals with greater technical knowledge.

4. Collaborative Advantage: The dominant players in all industries in the next decades will be those organisations that are successful at working collaboratively. The 21st century will be defined by the integration of competitive markets with new methods of collaboration.
5. NanoBio Future: Nanotechnology and biotechnology will dominate technological development in the next decades. Nanotechnology and biotechnology will be incorporated into all aspects of technology. They will provide the building blocks that future engineers will use to solve pressing problems in many fields.
6. Regulating Global Innovation: Innovation, within the framework of a global economy, will remain a complex affair. As more complex technologies require greater collaboration and sharing of patents, incremental changes will occur to produce equitable and beneficial results for the innovators and those that adopt and commercialize innovations.
7. Diverse Face of Engineering: Demand for new technologies will sustain the global demand for adequately skilled and innovative mechanical engineers. Prospective employers will seek and promote people with unique and varied backgrounds to maximize their potential for success in diverse cultures and situations.
8. Designing at Home: In the future, advances in computer aided design, materials, robotics, nanotechnology and biotechnology will democratize the process of designing and creating new devices. The engineering workforce will change as more engineers work at home as part of larger decentralized engineering companies or as independent entrepreneurs.
9. Engineering for the Other 90 Percent: In the next decades, globalization and new business models will increasingly drive the development of mechanical engineering projects that serve the poorest 90 percent of humanity.

Appendix 3: Intended learning outcomes

Bachelor's programme Mechanical Engineering

The goal of the Bachelor's programme Werktuigbouwkunde (Mechanical Engineering) is to educate Bachelors Mechanical Engineering (BSc) to exercise the profession of engineer at a professional academic level, who are able to:

• Identify, define and analyse problems, for the solution of which Mechanical Engineering principles and techniques can contribute;
• Systematically design and work out a sound solution;
• Effectively present this solution.

The programme shall ensure admittance to connecting Master's programmes.
In line with the TU Delft Profile for an Academic Engineer and the DSRK the following final qualifications have been defined, which serve to achieve the goal of the Bachelor's programme 'Werktuigbouwkunde':

The graduated Bachelor of Science Mechanical Engineering has, to a sufficient extent, the following qualities:

1. A broad and profound knowledge of the fundamental engineering sciences, which form the basis of Mechanical Engineering (mechanics, physical transport phenomena, thermodynamics, materials science, control engineering and mathematics), as well as some basic knowledge of related fields (electricity, magnetism, electronics, chemistry, informatics), to such a level that entrance can be obtained to internationally accredited Master of science programmes Mechanical Engineering. The ability to apply this knowledge on mechanical engineering systems.
2. A basic technical scientific knowledge of the most important Mechanical Engineering disciplines: mechanical systems, process and energy technology, mechatronics and production technology. The ability to apply this knowledge to design such systems.
3. A basic knowledge of methods and tools for modelling, simulating, designing and executing experiments and research on mechanical engineering systems. The ability to apply this knowledge.
4. The capability to contribute to the solution of technological problems by a systematic scientific approach. This includes the analysis, the definition of innovative solutions, the evaluation of the feasibility, the recognition and acquisition of missing knowledge, as well as recognition of the relativity and limitations of knowledge and the working out of the solution.
5. The capability of working individually as well as in (multidisciplinary) teams, taking initiatives where necessary.
6. The capability to effectively communicate (including presenting and reporting) about one's work with regard to information, problems, ideas and solutions to both professionals and non-specialised public.
7. The capability to evaluate and assess the technological, societal and ethical impact of one's work and to take responsibility with regard to sustainability, economy and social well-being. The ability to gather and interpret relevant information.
8. The ability to maintain and extend one's competences by permanent self study, with a high degree of autonomy.

Below an elaboration of the abovementioned final qualifications is given in its original Dutch form. This specifies the competences of the graduated Bachelor 'Werktuigbouwkunde' for each final qualification in more detail. The elaboration has been the basis for the courses within the major Mechanical Engineering (150 EC) and the learning goals for each course.

Uitgewerkte eindtermen voor de major werktuigbouwkunde (150 EC)

De bovengenoemde eindtermen zijn hieronder uitgewerkt. Deze uitwerking vormt de basis voor het vaststellen van de leerdoelen per curriculumonderdeel.

De afgestudeerde Bachelor of Science Werktuigbouwkunde heeft in voldoende mate de volgende kwaliteiten:

1. Brede en grondige kennis van de fundamentele ingenieurswetenschappen, die de basis van de werktuigbouwkunde vormen (mechanica, fysische transportverschijnselen, thermodynamica, materiaalkunde, regeltechniek en wiskunde), evenals enige basiskennis van aangrenzende gebieden (elektriciteit, magnetisme, elektronica, chemie, informatica), op een zodanig niveau dat toegang verkregen kan worden tot internationaal geaccrediteerde masteropleidingen 'werktuigbouwkunde'. Deze kennis actief kunnen toepassen op werktuigkundige systemen.

1.1. mechanica: krachten, spanningen en vervormingen bepalen en beoordelen in zowel statisch bepaalde als statisch onbepaalde 2D en 3D constructies (bestaande uit staven, balken, platen, volume-elementen) voor lineair-elastische isotrope en anisotrope materialen, voor geometrisch lineair en niet-lineair gedrag (instabiliteit van balk en plaatconstructies) en plastisch materiaalgedrag; het dynamische gedrag van massapunten en starre lichamen in 2D en 3D bepalen en de daarbij behorende krachten; het trillingsgedrag van discrete mechanische systemen met één en meerdere vrijheidsgraden modelleren en oplossen; het trillingsgedrag voor continue mechanische systemen, zoals staaf, as, snaar en balk modelleren en oplossen; principes en structuur van eindige elementen programmatuur.

1.2. fysische transportverschijnselen: integrale en differentiale behoudswetten voor massa impuls en energie toepassen; verschillende soorten stroming (laminair, turbulent, compressibel, niet-compressibel stationair, niet-stationair rond en langs lichamen, openwater) beschrijven; dimensieanalyse toepassen; stromingsberekeningen uitvoeren; eigenschappen en prestaties van roterende stromingsmachines (compressoren, pompen, turbines) afleiden en toepassen; verschillende soorten warmtetransport (geleiding, convectie, straling) beschrijven en stationair oplossen; niet-stationaire warmtegeleiding oplossen; warmteoverdracht berekeningen uitvoeren voor technische toepassingen (warmtewisselaars, ketels, verdampers, condensors, koelvinnen en isolatie); verschillende vormen van massatransport (diffusie, convectie) beschrijven.

1.3. thermodynamica: de verschillende vormen van energie (inwendige, warmte, arbeid, elektrische, potentiële, kinetische) beschrijven; thermodynamische grootheden en begrippen beschrijven, bepalen en toepassen; ideaal en niet-ideaal gedrag van gassen beschrijven en toepassen; 1e en 2e hoofdwet van thermodynamica beschrijven en toepassen; thermodynamische systemen (inclusief kringprocessen) op basis van de controle volume methode, van behoud van massa en energie, van energiebalansen, inclusief faseovergangen beschrijven, analyseren en optimaliseren; thermodynamische grootheden bij chemische reacties zoals verbranding bepalen.

1.4. materiaalkunde: inzicht in (micro)structuren, mechanische en fysische eigenschappen, corrosie en degradatie, productie en verwerking (vervormbaarheid, bewerkbaarheid) van materialen, zowel voor metalen, polymeren als composieten; op basis van die kennis een verantwoorde materiaalkeuze doen.

1.5. regeltechniek: modelvorming, blokdiagrammen, linearisering, oplossing responsie en simulatie van dynamische systemen; eigenschappen van 1e en 2e orde systemen; de invloed van de regeling op de dynamica van te regelen systemen analyseren en, door een juiste regelaarkeuze en instelling, het dynamisch gedrag optimaliseren o.a. door toepassing van frequentiedomein methoden; toestandsbeschrijving van systemen opstellen; karakteriseren, analyseren en bewerken van meetsignalen; tijd- en frequentiedomein analyse; Fouriertransformatie; continue, discrete-tijd en randomsignalen; correlatiefuncties en spectrale dichtheden van stochastische processen.

1.6. wiskunde: calculus, linaire algebra, gewone en partiële differentiaalvergelijkingen en statistiek tot een zodanig niveau dat voldoende wiskundekennis en vaardigheden aanwezig zijn om bovengenoemde eindtermen in de fundamentele vakgebieden te realiseren. Dit betreft o.a.: stelsels lineaire vergelijkingen oplossen, kleinste kwadraten methode toepassen, numerieke methoden toepassen om stelsels op te lossen; eigenwaarden en eigenvectoren bepalen; kwadratische vergelijkingen oplossen; lineariseren; differentiëren, partieel differentiëren; enkelvoudig en meervoudig integreren; complexe rekenwijze toepassen; vector operaties uitvoeren; analytisch limieten bepalen en benaderen d.m.v. reeksontwikkeling; functies benaderen met Taylor reeksen; minima en maxima van functies bepalen; lineaire, niet-lineaire en partiële differentiaal oplossen; stelsels van 1e orde lineaire differentiaal vergelijkingen oplossen; impliciete en expliciete partiële differentiaalvergelijkingen oplossen; op basis van kansdefinitie en kansverdeling, verzamelen, analyseren en conclusies (inclusief betrouwbaarheidsintervallen) trekken uit gegevens.

1.7. elektriciteit, magnetisme: kennis van elektriciteitsleer en magnetisme, zodanig dat de werking en eigenschappen van elektrische machines en sensoren kan worden begrepen.

1.8. elektronica: kennis van elektronica, zodanig dat versterkers en filters in mechatronische systemen toegepast kunnen worden.

1.9. chemie: inzicht in elementen uit de anorganische, organische en fysische chemie, die onmisbaar zijn als basis voor de procestechnologie: atomen/elementen, moleculen, ionen, chemische bindingen, mengsels.

1.10. informatica: kennis van computerarchitectuur o.a.: hardware, software, compileren, executeren, broncode, objectcode; voor programmeren zie 3.6.

2. Basis technisch-wetenschappelijke kennis van de belangrijkste werktuigkundige disciplines: mechanische systemen, proces- en energietechniek, mechatronica en productietechniek. Deze kennis actief kunnen toepassen voor het ontwerpen van dergelijke systemen.

2.1. mechanische systemen: opbouw en werkingsprincipes van mechanische systemen en werktuigen analyseren en beschrijven; mechanische systemen en werktuigen conceptueel ontwerpen en engineeren; werktuigonderdelen, verbindingen, overbrengingen en ondersteuningen kiezen, materialiseren, dimensioneren; de levensduur en de kwaliteit van functioneren van werktuigen en onderdelen beheersen door keuze van belasting, materiaal, smering en lagering; (elektrische) aandrijvingen selecteren, specificeren en dimensioneren.

2.2. proces- en energietechniek: opbouw en werkingsprincipes van proces- en energieconversie systemen en werktuigen analyseren en beschrijven; eenvoudige proces- en energieconversie systemen conceptueel ontwerpen en engineeren; de werktuigen in dergelijke systemen selecteren, specificeren en dimensioneren; ontwerpen van procesapparaten (reactoren en scheiders); maken van massa-, component en enthalpiebalansen, stroomdiagrammen, processchema's; verschillende scheidingsprocessen beschrijven, karakteriseren en berekenen.

2.3. mechatronica: opbouw en werkingsprincipes van mechatronische systemen, bestaande uit mechanische componenten, sensoren, elektronica, computers, micro controllers en actuatoren analyseren en beschrijven; fysische werkingsprincipes van meetinstrumenten, sensoren en actuatoren beschrijven; eenvoudige mechatronische systemen ontwerpen en engineeren inclusief de software; werktuigen en componenten in dergelijke systemen selecteren, specificeren en dimensioneren.

2.4. productietechniek: mogelijkheden en beperkingen van verschillende fabricagemethoden; opbouw van een productieproces en automatisering; de invloed van materiaaleigenschappen, productvorm, afmetingen, toleranties en seriegrootte op de fabricagekeuze.

3. Basiskennis van methodes en gereedschappen voor het modelleren, simuleren, ontwerpen en uitvoeren van experimenten en onderzoek van/aan werktuigkundige systemen. Het actief kunnen toepassen van deze kennis.
3.1. kennis van en vaardigheid met de toepassing van methodes en gereedschappen voor rapportage, presentatie, uitvoeren van berekeningen, dataopslag en verwerking, zoeken van informatie op het www, in databases en in bibliotheken.
3.2. visualiseren van werktuigkundige systemen en onderdelen in 2D en 3D met behulp van handschetsen en CAD software, het genereren van productie informatie hiermee.
3.3. methodes om het ontwerp en engineeringproces op een systematische wijze vorm te geven en uit te voeren, waaronder fasering en te gebruiken methodes en technieken.
3.4. onderzoeksmethodologie om onderzoek op systematische wijze vorm te geven en uit te voeren, waaronder uitwerking van de vraagstelling, formulering van hypotheses, opzet en uitvoering van het onderzoek, interpretatie van de resultaten.
3.5. opzetten en uitvoeren van experimenten, het gebruik van moderne data acquisitie en verwerkingssystemen, interpretatie van de resultaten.
3.6. de oplossing voor een probleem vertalen in een algoritme en uitwerken in een computerprogramma met behulp van een moderne object georiënteerde programmeertaal.
3.7. rekenproblemen en simulaties (numeriek) uitvoeren met een modern software pakket.
3.8. statisch en dynamisch lineair elastische analyses aan constructies uitvoeren, inhoudende het plannen, modelleren, uitvoeren en interpreteren van de resultaten met behulp van een modern eindig elementen pakket; zich de beperkingen realiseren van de gekozen modellering.

4. Een bijdrage kunnen leveren aan het oplossen van technologische problemen door een systematische wetenschappelijke aanpak. Dit betreft de analyse, het definiëren van innovatieve oplossingen, het onderkennen van de haalbaarheid, het onderkennen en verwerven van ontbrekende kennis, evenals de betrekkelijkheid en beperkingen van de kennis onderkennen en de uitwerking van de oplossing.
4.1. systematisch analyseren van problemen, waaronder ontwerpopdrachten en onderzoekvragen; het interpreteren van de analyseresultaten.
4.2. concipiëren van alternatieve en innovatieve oplossingen voor de vraagstelling.
4.3. onderzoeken van de technische, economische en maatschappelijke haalbaarheid van de oplossingen en het beargumenteerd maken van een keuze.
4.4. uitwerken van de gekozen oplossing tot een zodanig niveau dat implementatie kan plaatsvinden.

5. Vermogen zowel individueel als in (multidisciplinaire) teams te werken, waar nodig het nemen van initiatief.
5.1. zowel individuele opdrachten als opdrachten in teamverband uitvoeren.
5.2. projectvaardigheden verwerven waaronder planningen opstellen en bewaken, vergaderen, taken verdelen en coördineren, onderhandelen, omgaan met conflicten, eigen en andermans sterke en zwakke punten onderkennen.
5.3. uitvoeren van opdrachten met aanvankelijk goed gedefinieerde probleemstelling maar in latere fasen ook met een vage beperkt gedefinieerde probleemstelling, waarvoor de kennis en nodige informatie nog verworven moet worden.

6. Effectief kunnen communiceren (waaronder presenteren en rapporteren) over hun werk, t.a.v. informatie, problemen, ideeën en oplossingen aan zowel de professionele collegae als aan een niet-specialistisch publiek.
6.1. goed gestructureerde Nederlandstalige presentaties voor verschillende doelgroepen verzorgen met gebruik van state of the art presentatietechnieken.
6.2. schrijven van goed gestructureerde en heldere Nederlandstalige rapporten.
6.3. verworven kennis en resultaten van eigen werk helder en overtuigend overdragen.
aan anderen.

7. Kunnen evalueren van de technologische, maatschappelijke en ethische gevolgen van hun werk en de verantwoordelijkheid nemen met betrekking tot duurzaamheid, economie en sociale welzijn. In staat zijn om relevante informatie te verzamelen en interpreteren.
7.1. duurzame ontwikkeling beschrijven en operationaliseren waaronder schaarste, milieuproblematiek, duurzaam energie- en grondstoffengebruik, rol van de techniek daarin.
7.2. morele problemen onderkennen; beargumenteren welke actoren daarbij een rol spelen en de rol van een ingenieur; normatieve en feitelijke beweringen; wettelijke, technische en morele eisen; zuiver argumenteren.
7.3. veiligheidsrisico's kwalitatief en kwantitatief bepalen; methoden om veiligheidsrisico's in te perken.
7.4. economische haalbaarheid van technische oplossingen beoordelen.
7.5. Nederlandse en Engelse literatuur lezen, interpreteren en samenvatten; idem bij mondelinge communicatie.

8. Het op peil houden en uitbreiden van de eigen competenties door permanente zelfstudie, met een hoog niveau van autonomie.
8.1. zich realiseren dat ontwikkelingen op gebied van wetenschap, techniek, methoden en gereedschappen in hoog tempo gaan.
8.2. noodzaak voor eigen verdere ontwikkeling onderkennen.

Master's programme Mechanical Engineering

The goal of the Master programme Mechanical Engineering is to educate graduates in Mechanical Engineering (MSc) to exercise the profession of engineer at a professional academic level. The level corresponds to the technological borders of a specific discipline.

The graduates are capable:

• To identify, define and analyse problems, for the solution of which Mechanical Engineering principles and techniques can contribute.
• To design and produce a sound solution to the problem.
• To present these solutions effectively.

In line with the TU Delft Profile for an Academic Engineer and the DSRK, the following final qualifications have been defined, which serve to achieve the goal of the Master programme Mechanical Engineering:

The graduated Master of Science Mechanical Engineering meets, to a sufficient level, the following qualifications:

1. A broad and profound knowledge of engineering sciences (applied physics, mathematics), relevant to a specific mechanical engineering discipline and the capability to apply this knowledge at an advanced level in that discipline.
2. A broad and profound scientific and technical knowledge of the relevant discipline and the capability to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative discipline related systems, with an appreciation of different application area's.
4. The capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub problems, providing innovative technical solutions, also in a new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. The capability of working both independently and in (multidisciplinary) teams, taking initiatives where necessary.
6. The capability to effectively communicate (including presenting and reporting) to both professionals and non specialised public in the English language about one's work, such as solutions to problems, conclusions, knowledge and considerations.
7. The capability to evaluate and assess the technological, ethical and societal impact of one's work and to take responsibility with regard to sustainability, economy and social well-being. Capability to come to conclusions with incomplete and limited information.
8. The attitude to independently maintain professional competence through life-long learning.
These final qualifications have the same structure as those for the Bachelor programme, but are differing with respect to both domain-specific and general qualifications and level.

The master programme is offered in seven different tracks:

- Materials Engineering and Applications
- Biomechanical Design (BMD)
- Control Engineering (CE)
- Precision and Microsystems Engineering (PME)
- Solid and Fluid Mechanics (SFM)
- Sustainable Process and Energy Technology (SPET)
- Transportation Engineering (TE)

A track covers a cluster of specialisations within the study programme. For each track a coherent curriculum has been defined.
Within a track it is possible to carry out the master thesis project under the guidance of one of the professors that have their speciality within the field of the track. This leads to a large number of different specialisations. These tracks with specialisations are described in the study guide.
For each track the final qualifications have been elaborated in more detail. The elaborated final qualifications show the competences of the graduated Master of Science in Mechanical Engineering. The elaborated final qualifications are the basis for the obligatory courses within each track and the learning goals of each course.

Descriptions
The domain-specific requirements are described in the (elaborated) final qualifications 1 (knowledge of the fundamental engineering sciences relevant for a specific Mechanical Engineering discipline (track)), 2 (domain knowledge of a specific Mechanical Engineering discipline (track)) and 3 (knowledge of methods and tools relevant for that discipline).
The final qualifications for the master programme Mechanical Engineering have been defined by the Director of Education in consultation with the teaching staff and the Education Committee. The viewpoints of professors and staff about the study programme are influenced by their national and international contacts with industry R&D and other universities. The international contacts involve different universities, research institutes and different companies depending on the track.
Both the elaborated track final qualifications and programmes have been discussed in and approved by the Education Committee. Next to that, the Professional Review Committee has studied and commented upon the elaborated final qualifications of all tracks. This ensures that the track programmes get support from industry and comply with their needs. Finally each track has been benchmarked by comparing them with equivalent study programmes of a number of prominent European universities. The documents, supporting these actions, will be available for the visitation committee during their visit.
In this way it has been ensured that the final qualifications comply with international standards and with the needs of the professional community.

Master' programme-ME Track BMD
Final Qualifications of the track 'Biomechanical Design' within the master programme 'Mechanical Engineering'
The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are able:

• To identify, define and analyse problems, for the solution to which mechanicalengineering principles and techniques can contribute;
• To develop and to produce a sound solution to the problem;
• To present these solutions effectively.

Biomechanical Systems are technical systems which are designed for interaction with biological systems or designed following the principles of biological systems. The track Biomechanical Design has four specialisations: BioRobotics (BR), BioCompatible Design (BCD), Intelligent Mechanical Systems (IMS), and Automotive (AUT). Examples in these fields that nourish education are, respectively, for BR: the design of two-legged walking robots, haptic systems; for BCD: the design of steerable instruments for surgery based on a squid tentacle, grasping mechanisms for irregular shapes such as in hand prosthetics; for IMS: intelligent design such as integrating of CAD and control and simulation software, light-weight design and light machine manufacturing; and for AUT: human motion control, biomechanics, car-driver system analysis and control, and (force)feedback from the car to the driver.

The graduated Master of Mechanical Engineering in the track Biomechanical Design meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences (applied physics and mathematics) and the capability to apply this knowledge at an advanced level in the Biomechanical-Systems discipline.

2. Specific field of knowledge:
a. Broad and profound scientific and technical knowledge of the Biomechanical-Systems discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
b. Broad and profound knowledge of biological systems, with the emphasis the human, and of biophysical modelling, in order to optimise the interaction with the biocompatible systems and to get inspiration for innovative technical solutions.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Biomechanical systems, with an appreciation of different application areas.
4. Capability to independently solve technological and biophysical problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social well-being.
8. Attitude to independently maintain professional competence through life-long learning.

For defining the specific goals per subject within the master track Biomechanical Design, the above-mentioned final qualifications have been elaborated as follows:

1. Broad and profound knowledge of engineering sciences (applied physics and mathematics) and the capability to apply this knowledge at an advanced level in the Biomechanical-Systems discipline.
In addition to the knowledge obtained in a BSc programme:

• Analysing the motions of linked rigid body systems in two and three dimensions including systems with various kinematic constraints (sliding, hinges and rolling, closed kinematic chains).
• Modelling of mechatronic systems, parameter estimation, design and computer implementation of digital controllers, practical laboratory sessions.
• Static and dynamic performance of mechanical measurement systems, conditioning, transmission and manipulation of measurement data, measurement devices.
• Usage of multibody dynamics software, appreciate the limitations and draw sensible conclusion about the modelled system.
• Kinematics, dynamics and kinetostatics of mechanisms with multiple degrees of freedom, design optimization and modelling. Theoretical knowledge and practical skills in the design of production machines.

• Systematic and holistic approach to product life cycles, including marketing, design, production, logistics, use, maintenance, recovery and recycling.
• Theoretical foundation behind computer-based engineering tools, including numerical computation, data structures, intelligent algorithms.
• Modelling of mechatronic systems, parameter estimation, design and computer implementation of digital controllers, practical laboratory sessions.

2. Specific field of knowledge:
a. Broad and profound scientific and technical knowledge of the Biomechanical-Systems discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
• Interaction between humans and technical systems, in which the human is considered part of the control loop, ranging from manual to supervisory control. Specifications of human sensory systems, actuator systems and processing of information.
• Improving performance of technical systems by implementing intelligent controllers, capable of advanced decision making based on well-chosen input and output signals and data management.
• Design of autonomous operating humanoid robot systems, capable of human-like actions and interaction, which should be energy efficient and have autonomous control. The humanoid robot systems include vision systems, collaboration with other robots, legged locomotion.
• Practical assignment for the realization of a new design for a tele-robotics system (master-slave) with force feedback.
b. Broad and profound knowledge of biological systems, with the emphasis on human beings, and of biophysical modelling, in order to optimise the interaction with the biocompatible systems and to get inspiration for innovative technical solutions.
• Biomechanics and modelling of musculoskeletal systems, including sensors, muscles and Central Nervous System. Control of posture and motions.
• Use of control theoretical principles for the improvement of mechanical system behaviour, applied to medical systems, e.g. for diagnosis and treatment.
• Biophysical modelling of physiological systems, such as the cardiovascular system, lungs, kidneys, and central nervous system.
• Non-conventional mechanical approaches in biology, which can be used to inspire creativity in mechanical design.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Biomechanical systems, with an appreciation of different application areas.
• Methods for executing research or design projects in particular related to human behaviour, interaction between humans and their technical environment, and intelligent machines.
• In addition to general methods emphasis is placed on multidisciplinary problems.

4. Capability to independently solve technological and biophysical problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and

integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
4.1. Capability to decompose complex problems into sub-problems, to analyse these subproblems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. Capability to independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. Capability to conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. Capability to conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.
5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques.
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his / her own position.
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions

8. Attitude to independently maintain professional competence through life-long learning.
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master 's programme Track CE
Final Qualifications of the track 'Control Engineering Design' within the master's programme 'Mechanical Engineering'.

The goal of the track Control Engineering in the master programme Mechanical Engineering is to educate graduates in Control Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable:

- To identify, define and analyse problems, for the solution to which systems-and-control principles and techniques can contribute;
- To develop and to produce a sound solution to the problem;
- To present these solutions effectively.

The programme is directed towards the analysis and design of reliable and high-performance measurement and control strategies for a wide variety of technological dynamical processes. It is centred on fundamental generic aspects of systems and control engineering, while it stresses the multidisciplinary character of the field concerning its applications in mechanical engineering, such as

- High-accuracy positioning and motion control systems as addressed in Mechatronics and Microsystems, Production systems, Robotics and Smart structures;
- (Petro)chemical/physical and biotechnological production processes;
- Transportation systems (automotive systems, logistic systems, aerospace);
- Energy systems.

The programme brings together issues of physical modelling, experiment design, signal analysis and estimation, model-based control design and optimisation, hardware and software aspects, in the scope of studying systems of high complexity and of different nature, such as linear and nonlinear dynamics, hybrid and embedded systems, and ranging from small-scale microsystems to large-scale industrial plants.
The graduated Master of Mechanical Engineering in the track Control Engineering meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of mechanical engineering and the capability to apply this knowledge at an advanced level in the systems-and-control-engineering discipline.
2. Broad and profound scientific and technical knowledge of the systems-and-control engineering discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new insights.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative technological dynamical systems, with an appreciation of different application areas of mechanical engineering.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
8. Attitude to independently maintain professional competence through life-long learning.

Elaborated final qualifications of the master track programme Control Engineering:
For defining the specific goals per subject within the track Control Engineering of the master programme Mechanical Engineering, the above-mentioned final qualifications have been worked out as follows:

1. Broad and profound knowledge of mechanical engineering and the capability to apply this knowledge at an advanced level in the systems-and-control-engineering discipline.
In addition to the required knowledge obtained in a bachelor or pre-master programme:
1.1 Understanding common features within diverse engineering disciplines by relying on the abstract viewpoint and concepts (signals, systems, interconnections, feedback) of systems and control.
2. Broad and profound scientific and technical knowledge of the systems-and-control engineering discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new insights.
2.1 Knowledge of methods for modelling dynamical systems based on physical principles, and knowledge of principles of modelling dynamical systems on the basis of measured input-output data. Understanding of optimization in system identification and knowledge of practical aspects of black-box modelling (experiment design) as well as ability to apply them to concrete modelling tasks.
2.2 Knowledge of the concepts and techniques used in modern control theory. Mastering state-space control theory for analysing stability, controllability and observability and for designing optimal controllers and Kalman filters.
2.3 Ability to integrate the theoretical foundations in the practical design cycle for control of systems in the field of mechanical engineering: Modelling, parameter estimation, system analysis, feedback controller synthesis, real-time implementation of controllers, and validation of the designed control system. Acquaintance with modern technological tools.
2.4 Acquire specialized knowledge of systems and control theory and how it is intertwined with mechanical systems or chemical and production processes. Develop in-depth-knowledge of at least one subject within the discipline at the forefront of scientific or industrial research, at a level enabling a thorough understanding of the international literature.
2.5 Actively acquire an overview of the relevant developments and structural relations within in the field of mechanical engineering and control and an understanding of their impact in other fields, in particular concerning the design of advanced technological systems.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative technological dynamical systems, with an appreciation of different application areas.
3.1 Thorough mastery of the theoretical foundations for modelling, analysing and optimally designing dynamical systems. This includes a clear understanding of presuppositions,

limitations and the evolution of existing theory, as well as the ability to put them into question and to propose adjustments with a clear view on the corresponding implications.
3.2 Profound knowledge about first-principle and experimental modelling of dynamical systems, including techniques for their validation on the basis of measured data. Ability to judge the usefulness of models for the purpose of analysis, simulation and optimal controller design for advanced application areas.
3.3 Skills to integrate and independently apply theoretical knowledge and modelling techniques to complex dynamical mechanical or process systems in computer simulations and in a real-world laboratory environment, as well as within application supported by modern computational, simulation and implementation tools.
3.4 Capacity to assess scientific research in systems and control and its usefulness for analysis and design of advanced technological dynamical systems. Creativity to discover new viewpoints and put them into practice in the realm of new applications, with an appreciation of the relevance of and an open attitude to draw upon other disciplines within own research.
3.5 Ability to model, analyse and interpret dynamical systems in the basic engineering domains.

4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing or developing new knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
4.1. Capability to decompose complex problems into sub-problems, to analyse these subproblems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. Capability to independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. Capability to conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. Capability to conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.
5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.

6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques.
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social well-being.
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his/her own position.
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions.

8. Attitude to independently maintain professional competence through life-long learning.
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master's programme-ME Track PME
Final Qualifications of the track Precision and Microsystems Engineering (PME) within the master programme 'Mechanical Engineering'.
The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable:

• To identify, define and analyse problems, for the solution to which mechanical engineering principles and techniques can contribute;
• To develop and to produce a sound solution to the problem;
• To present these solutions effectively.

The purpose of the Track in Precision and Microsystems Engineering is to educate engineers to analyse, design and implement solutions applicable in many different fields including IC manufacturing, biomechanics, smart microsystems, high tech production and assembly, automotive and aerospace design. With this focus on the small world, the programme confronts students with the daunting conceptual and design challenges of developing (and utilising) tools for precision mechanical engineering, while also addressing the needs of the modern society.
The graduated Master of Mechanical Engineering in the track Precision and Microsystems Engineering meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences (applied physics, mathematics, control theory) and the capability to apply this knowledge at an advanced level in the Precision and Microsystems Engineering discipline.
2. Broad and profound scientific and technical knowledge of the Precision and Microsystems Engineering discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Precision and Microsystems Engineering systems, with an appreciation of different application areas.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
8. Attitude to independently maintain professional competence through life-long learning.

Elaborated final qualifications of the track Precision and Microsystems Engineering within the master's programme Mechanical Engineering:
For defining the specific goals per subject within the master track Precision and Microsystems Engineering, the above-mentioned final qualifications have been worked out as follows:

1. Broad and profound knowledge of engineering sciences (applied physics, mathematics, etc.) and the capability to apply this knowledge at an advanced level in the discipline on Precision and Microsystems Engineering.
In addition to the required knowledge obtained in a bachelor or pre-master programme:
Generic PME programme
• Knowledge about the fundamentals of advanced control system descriptions, such as space state descriptions of linear dynamic systems, stability theory and frequency domain analysis;
• Overview of important mechanical phenomena and guidelines for modelling and solving structural analysis problems in the PME domain like vibration analysis of structures, multi-physical aspects of modelling, visco-elasticity of (composite) materials

2. Broad and profound scientific and technical knowledge of the Precision and Microsystems Engineering discipline and the skills to use this knowledge effectively.
The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
Generic PME programme
• Building awareness an feel for microsystems, their application, manufacture and design aspects of these microscopic systems.
• Comprehension of mechatronic systems containing mechanical structures, actuators and sensors (dynamic behaviour, structural resonances, damping).
• Knowledge to design assembly and packaging processes for hybrid MEMS.
• Statistical and dynamical performance of mechanical measurement systems, conditioning, transmission and manipulation of measurement data, measurement devices.

• Learning and applying mechanical design principles in precision engineering applications.
• Measure friction and wear parameters in precision engineering applications.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Precision and Microsystems Engineering systems, with an appreciation of different application areas.
Generic PME programme
• Hands-on experience with state-of-the-art measurement and control equipment and integration of this equipment in an experimental setup.

4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing or developing new knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
4.1. Capability to decompose complex problems into sub-problems, to analyse these subproblems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. Capability to independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. Capability to conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. Capability to conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.
5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his/her own position.
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions.

8. Attitude to independently maintain professional competence through life-long learning.
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master's programme-ME Track SFM
Final Qualifications of the track Solid and Fluid mechanics within the master's programme 'Mechanical Engineering'. The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable:

• To identify, define and analyse problems, for the solution to which mechanical engineering principles and techniques can contribute;
• To develop and to produce a sound solution to the problem;
• To present these solutions effectively.

Design, modelling and control of most practical structures and systems relies on solid and/or fluid mechanics. Driven by rapid development in computer and information technology over the last decades, attention has been shifted from analytical approaches towards numerical models and techniques. For these reasons computational mechanics and computational fluid dynamics are among the keystones of many engineering disciplines, for example aeronautics and civil and mechanical engineering.
Obviously, new theories and models require experimental validation. The master's programme Solid and Fluid Mechanics is organized as a two-year study devoted to the fundamentals of contemporary mechanics. This implies that a variety of courses are embedded, addressing the fundamentals of the governing theories, numerical solution procedures and discretization techniques. The solid and fluid mechanics programme gives and excellent basis for those aiming at research carrier in industry or academia.

The graduated Master of Mechanical Engineering in the track Fluid and Solid mechanics meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences (applied physics, mechanics mathematics and computational mechanics) and the capability to apply this knowledge at an advanced level in the fluid and solid mechanics discipline.
2. Broad and profound scientific and technical knowledge of the fluid and solid mechanics and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with

respect to innovative solid and fluid mechanical systems, with an appreciation of different application areas.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
8. Attitude to independently maintain professional competence through life-long learning.

Elaborated final qualifications of the track solid and fluid mechanics within the master programme Mechanical Engineering:
For defining the specific goals per subject within the master track fluid and solid mechanics, the above-mentioned final qualifications have been worked out as follows:

1. Broad and profound knowledge of engineering sciences (applied physics, mechanics mathematics, and computational mechanics) and the capability to apply this knowledge at an advanced level in the fluid and solid mechanics discipline. In excess of the knowledge obtained in the Bachelor programme of Mechanical Engineering:
In addition to the required knowledge obtained in a bachelor or pre-master programme:

• Concepts of classical mechanics: Tensor and tensor algebra, Lagrangian and Eulerian description of deformations and motions. Deformation and strain tensors.
• Concepts of classical fluid mechanics: Navier-Stokes equations, vorticiy, potential flow theory, Stokes flow, boundary-layer theory,
• Concepts of classical dynamics: Equations of motion dynamical systems, harmonic response, vibrations and finite elements.
• Concepts of computational fluid dynamics: Finite difference methods, finite volume methods, grid generation, solution of the Navier-Stokes equations.

2. Broad and profound scientific and technical knowledge in one of the four specialisations within the solid and fluid mechanics programme and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
Depending on the chosen specialisation the student composes, under supervision of its graduation professor, a study programme from the list of electives in such a way that the following knowledge is covered:

• Fluid Mechanics (FM): Basic understanding of turbulent and multi-phase flow. Numerical modelling of these flows using (commercial) CFD software. Experimental techniques for

flow measurements. Understanding of possibilities and limitations of experimental and numerical techniques.
• Engineering dynamics (ED): Fundamentals of structural vibrations and multi body dynamics and tools to handle such problems. Coupling with fluid flow and/or electromagnetic fields.
• Mechanics of Materials(MM): Profound insight in the mechanical properties of materials, via analytical, numerical and experimental techniques. Virtual prototyping.
• Structural Optimisation & Computational Mechanics(SO): Computer aided design and optimisation. Understanding and knowledge of both computational mechanics and optimisation. Applications in Micro-Electrical –Mechanics-Systems (MEMS)

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative fluid and or solid mechanical systems, with an appreciation of different application areas.
• Thorough knowledge of theoretical foundations for modelling, analysis and optimal design of fluid and solid mechanical systems. This includes a clear understanding of the limitations of theory and modelling.
• Knowledge of experimental techniques used in the field of fluid and solid mechanics, including data analysis in wavenumber space/frequency domain.
• Skills to integrate and apply theoretical and experimental techniques to study complex fluid and or solid mechanical systems.

4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing or developing new knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
4.1. Capability to decompose complex problems into sub-problems, to analyse these subproblems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. Capability to independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. Capability to conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. Capability to conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary:
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.

5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques.
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing. The solid and fluid mechanics has two annotations to broaden the knowledge in the fields of:
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his / her own position.
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions.

8. Attitude to independently maintain professional competence through life-long learning.
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master's programme-ME Track SPET

Final Qualifications of the track 'Sustainable Process and Energy Technologies' (SPET) within the master programme 'Mechanical Engineering'.
The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable:

• To identify, define and analyse problems, for the solution to which mechanical engineering principles and techniques can contribute;
• To develop and to produce a sound solution to the problem;
• To present these solutions effectively.

Sustainable Process and Energy Technologies cover technical challenges that occur in one of the principal industrial contributors to our economy: the process industry in general and more specifically the petroleum, chemicals, food and energy producing industry. Although these are well-established industrial area, there are nevertheless many new developments, which require improved and/or new technologies. To mention only a few: there is a lasting need to drastically improve process efficiency of product quality while at the same time the impact on the environment of these processes and their energy consumption should be kept to an acceptable minimum. For these reasons innovative sustainable technologies must be developed and then incorporated in new designs, which eventually must find their way in industry.
The SPET curriculum involves two specialisations: Energy Technology (ET) and Process Technology (PT). The objective of the different specialisations is to develop a thorough knowledge of:

• Technologies for energy generation, conversion and utilisation (ET).
• New concepts of sustainable process technologies (PT).

The SPET curriculum prepares graduates to pursue a career in both the industry, where design and development play a major role, and academia, where science has a larger share. Most SPET graduates find employment in process and energy related jobs.
The graduated Master of Mechanical Engineering in the track Sustainable Process and Energy Technologies meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences (applied physics and mathematics) and the capability to apply this knowledge at an advanced level in the Sustainable Process and Energy Technologies discipline.
2. Specific field of knowledge:
Broad and profound scientific and technical knowledge of the Sustainable Process and Energy Technologies discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Sustainable Process and Energy Technologies, with an appreciation of different application areas.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
8. Attitude to independently maintain professional competence through life-long learning.

Elaborated final qualifications of the track Sustainable Process and Energy Technologies within the master programme Mechanical Engineering.
For defining the specific goals per subject within the master track Sustainable Process and Energy Technologies, the above-mentioned final qualifications have been worked out as follows:
1. Broad and profound knowledge of engineering sciences (applied physics and mathematics) and the capability to apply this knowledge at an advanced level in the Sustainable Process and Energy Technologies discipline.
In addition to the required knowledge obtained in a bachelor or pre-master programme:

• The fundamentals of classical, incompressible fluid mechanics with the purpose of solving fluid mechanics problems.

• The theory of heat transfer by conduction, convection and radiation with the purpose of determining the dimensions of heat transfer equipment.
• The theory of mass transfer phenomena with the purpose of sizing equipment for physical separation processes.
• The thermodynamic fundamentals of pumps, compressors and turbines with the purpose of sizing fluid machinery.

Specific for the specialisation in Energy Technology:

• The concept of exergy and its application to evaluate and improve the thermodynamic performance of various conversion processes and systems.
Specific for the specialisation in Process Technology:
• The concept of phase equilibria and thermodynamic potential in ideal and non-ideal mixtures of substances.

2. Broad and profound scientific and technical knowledge of the Sustainable Process and Energy Technologies discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge. Basic concepts in the Sustainable Processes and Energy Technologies discipline at BSc level are augmented with technical knowledge and skills:

• To solve fluid mechanics problems encountered in Sustainable Process and Energy Technologies related scientific and / or industrial research and development.
• To formulate and solve models of chemical and energy conversion processes using thermodynamics, fluid dynamics and heat and mass transfer principles.
• To use commercial computational fluid dynamics (CFD) packages properly keeping a critical attitude towards the reliability of the results of numerical simulations.
• To conceptually design and optimize chemical or energy related processes including their overall ecological and economical performance.
• To use the control theory and apply it to dynamic models and simulations of applications in chemical and energy conversion processes.
• To select suitable equipment for heat transfer and to determine its dimensions. To apply pinch technology to heat integration.
• To select and size process equipment.
• To apply the specific characteristics and application range limitations of pump, compressor and turbine types.
• To apply the concepts and analysis strategies of sustainable development for the sustainability assessment of chemical and energy conversion processes.
• To discuss the interdependencies between energy and worldwide developments in our society, economy and requirements towards sustainability and environmental protection. To overview the resources of fossil and renewable energies.

Specific for the specialisation in Energy Technology:

• To contribute to the development of highly efficient, environmentally friendly and integrated processes for the production and utilization of heat, power and secondary fuels like hydrogen.

• To apply thermodynamic concepts to refrigeration machines taking into account their economic and environmental impact.
• To reduce overall thermodynamic (exergy) losses of processes and systems used for chemical or energy conversion.

Specific for the specialisations in Process Technology:

• To contribute to the development of highly efficient, environmentally friendly and intensified processes and equipment for the process industry.
• To use strength of materials and fluid dynamics fundamentals in the selection of materials and design of equipment for the energy and process industries.
• To solve chemical-physical process problems in the area of phase and chemical equilibria for both pure components and mixtures under ideal and non-ideal process conditions.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative Sustainable Process and Energy Technologies' systems, with an appreciation of different application areas. The knowledge at BSc level is extended with:

• Methodology to model the steady state and dynamic behaviour of chemical and energy conversion processes using basic principles and fundamental engineering knowledge in the fields of thermodynamics, fluid dynamics and heat and mass transfer.
• Methodology to model, solve and analyse problems in fluid dynamics making use of commercial computational fluid dynamics (CFD) packages.
• Methodology to conceptually design and optimize chemical or energy related processes including their overall ecological and economical performance.
• Control strategies and their application to models and simulations of applications in chemical and energy conversion processes.

4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations. The student has demonstrated his capability to:
4.1. decompose complex problems into sub-problems, to analyse these sub-problems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary. The student has demonstrated his capability to independently and in consultation with specialists:
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.
5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language. The student has proven to be capable of communicating about his:
6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques.
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
The student has demonstrated his capability to:
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his / her
own position
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions.

8. Attitude to independently maintain professional competence through life-long learning.
The student has shown his life-long learning competence by:
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master's programme-ME Track TE

Final Qualifications of the track 'Transportation Engineering' within the master's programme 'Mechanical Engineering'.
The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable:

• To identify, define and analyse problems, for the solution to which mechanical-engineering principles and techniques can contribute;
• To develop and to produce a sound solution to the problem;
• To present these solutions effectively.

Essential tasks of Transportation Engineers are to develop, design, build and operate transport systems and equipment to transport people and to transport and handle goods. Examples of those systems are for instance ship mechanical and electrical installations aboard ships, harbour systems and equipment, conveyor belts in mines, at airports and in productions plants. Systems and equipment are considered as an indivisible part of a supply chain. Advanced, fast and safe marine and transport systems are required to maintain an acceptable level of mobility and freedom of transportation and to guarantee the competitive position of companies involved. New generation marine, transport and industrial systems have to be based on new concepts, using distributed intelligence, combined with the application of smart components. To be able to design these new systems, fundamental knowledge of the dynamics of and the physical processes in marine, transport and industrial systems, the logistics of the systems and the interaction between the equipment and the control systems is essential.

The programme track Transportation Engineering has four specialisations: Transport Engineering and Logistics (TEL); Production Engineering and Logistics (PEL); Mechanical Systems and Integration (MSI) and Diesel Engines (DE).
The graduated Master of Mechanical Engineering in the track 'Transportation Engineering' meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences, physics and mathematics, and the capability to apply this knowledge at an advanced level in the 'Transportation Engineering' discipline.
2. Broad and profound scientific and technical knowledge of Transportation Engineering and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative transportation systems, with an appreciation of different application areas.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work, such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social well-being.
8. Attitude to independently maintain professional competence through life-long learning.

Elaborated final qualifications of the track 'Transportation Engineering' within the master programme Mechanical Engineering.
For defining the specific goals per subject within the master track 'Transportation Engineering', the above-mentioned final qualifications have been worked out as follows:

1. Broad and profound knowledge of engineering sciences (applied physics, mathematics,

etc.) and the capability to apply this knowledge at an advanced level in the 'Transportation Engineering' discipline.
Transportation Engineering builds on the knowledge of engineering science obtained in the BSc programme. Knowledge of mathematics, physics, production engineering, system science, computer science is considered essential. For certain specialisations, additional fundamental knowledge is required. Specialisations Mechanical Systems and Integration and Diesel Engines require more fundamental knowledge on thermodynamics, and for Transport Engineering and Logistics additional knowledge the stactical and dynamical behaviour of mechanical installations is needed.
The students have to be able to apply the various fundamental engineering sciences at an advanced level in the field of Transportation Engineering. Understanding what type of fundamental knowledge is required for a certain Transportation Engineering related problem, and how to combine and apply this knowledge is an important qualification within the disciple of Transportation Engineering.

2. Broad and profound scientific and technical knowledge of the "Transportation Engineering' discipline and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in part the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new designs or development of new knowledge.

The more specific scientific and technical knowledge required for Transportation Engineering differs for the various specialisations.

For students in Transport Engineering and Logistics, broad and profound knowledge is required of the various types of cargo to be transported, the equipment required to transport and handle these different types of cargo, and the logistics needed to control these transport systems. Students must understand the characteristics of the different types of cargo, the equipment, and the logistics systems and must be able to design and develop such systems.
For students in Production Engineering and Logistics, broad and profound knowledge is required of the environment in which transport systems operate, and of the control mechanisms required to manage these systems as a whole. Students must understand the characteristics of the different operational systems, their logistics and their information systems. They must be able to formulate logistic problems unambiguously, to develop solutions and to communicate in an interdisciplinary environment.

For students in Mechanical Systems and Integration, broad and profound knowledge is required of machinery and electrical equipment (operational principles as well as such characteristics as controllability and maintainability) as well as of fluid dynamics, mechanical vibrations and strength, thermodynamics, reliability and maintainability. Students must understand the characteristics of the different operational systems in order to integrate the different equipment to create well-functioning, efficient and cost-effective systems.

For students in Diesel Engines, broad and profound knowledge is required of the interaction between the components and subsystems which make up an engine. Students must understand the characteristics, the application of these systems in order to making the diesel engine an environmentally friendly, low-cost and low-maintenance element in mechanical installations.

3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing research with respect to innovative transportation systems, with an appreciation of different application areas.

The paradigms, methods and tools required for the different specialisations:
Students in Transport Engineering and Logistics student must be able to model, simulate and design equipment and transport systems using advanced computer simulation tools. Knowledge is required on the modelling of equipment for both the static and dynamic analysis, and the modelling and control of logistics systems for analysing e.g. the performance of a system.
Students in Production Engineering and Logistics must be able to model, simulate, design and control industrial systems, recognizing the restrictions of the technological domain. They are required to master the Delft Systems Approach and Process Interaction Simulation, in order to design and implement operational structures that will perform according policy-defined criteria.
Students in Mechanical Systems and Integration must be able to model and control the different operational systems and use simulation to develop and to prove the functionality of the integrated well-functioning, efficient and cost-effective systems.
Students in Diesel Engines must be able to use a system approach to developing engines of the future in relation to sea state and manoeuvring in ships and sustainability in terms of low fuel consumption and emissions.

4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing or developing new knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
4.1. Capability to decompose complex problems into sub-problems, to analyse these subproblems and formulate innovative solutions, and to interpret the results in terms of the overall problem formulation. This includes the ability to detect and reformulate ill-posed research and design problems and to suggest remedies.
4.2. Capability to independently formulate and execute a research or design plan, and to steer adaptations if required by technological developments within the discipline or by changing external circumstances.
4.3. Capability to conceive knowledge gaps and to independently acquire expertise through studying the scientific literature on the discipline and/or to acquire this knowledge through other experts. Skill to contribute to the development of scientific knowledge or to design techniques in the area of specialisation.
4.4. Capability to conceive alternative and innovative solutions to discipline-related problems, including the ability to work out the chosen solution up to the level of real-life implementation.

5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
5.1. Capability to work independently and in teams on problems of high technological and/or scientific complexity.
5.2. Capability to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.

5.3. Capability to handle tasks which initially seem straightforward, but at a later stage require additional knowledge.

6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
6.1. Give well-structured presentations for different audiences using state-of-the-art presentation techniques.
6.2. Write well-structured and clear reports and contributions to scientific papers.
6.3. Convey acquired knowledge and results to others in a clear and convincing way.
6.4. Read, interpret and summarise literature; idem for verbal communication.

7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social wellbeing.
7.1. Describe and implement sustainable development.
7.2. Recognise moral issues, argue who play a role in these and be aware of his/her own position.
7.3. Assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
7.4. Analyse and assess the technical, economic and social feasibility of engineering solutions.

8. Attitude to independently maintain professional competence through life-long learning.
8.1. Awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Master's programme-ME Track MEA

The goal of the master programme Mechanical Engineering is to educate graduates in Mechanical Engineering to an academic engineering level. The level corresponds to the technological borders of a specific discipline. The graduates are capable to:

- Identify, define and analyse problems, for the solution to which mechanical-engineering principles and techniques can contribute;
- Develop and produce a sound solution to the problem;
- Present these solutions effectively.

Materials Engineering and Applications is an interdisciplinary field involving the study of physical, chemical and mechanical aspects of material properties, production processes and materials selection in the context of a wide range of engineering applications. Such knowledge on materials is essential to optimise designs in Mechanical Engineering. The track programme Materials Engineering and Applications provides a comprehensive treatment linking mechanical engineering applications to material-specific aspects, such as relations between materials processing and the resulting microstructure, between microstructure and the resulting properties and between properties and design aspects.

The graduated Master of Mechanical Engineering in the track Materials Engineering and Applications meets, to a sufficient level, the following qualifications:

1. Broad and profound knowledge of engineering sciences, physics, mathematics and chemistry, and the capability to apply this knowledge at an advanced level in the materials-engineering-and-applications discipline.

2. Broad and profound scientific and technical knowledge of Materials Engineering and Applications and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in numerous instances the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new knowledge on materials or materials-driven development of new designs.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing re-search with respect to materials-related aspects in mechanical engineering design.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social well-being.
8. Attitude to independently maintain professional competence through life-long learning.

Specification of the final qualifications of the track programme Materials Engineering and Applications:
For defining the specific goals per subject within the master track Materials Engineering and Applications, the above-mentioned final qualifications have been worked out as follows:

1. Broad and profound knowledge of engineering sciences, physics, mathematics and chemistry, and the capability to apply this knowledge at an advanced level in the materials-engineering-and-applications discipline.

In addition to the required knowledge obtained in a bachelor or pre-master programme:

- Physics: solid state physics, waves, quantum mechanics;
- Inorganic and organic chemistry as well as electrochemistry: reactions in solutions and in the solid state, equilibria, polymerisation, precipitation;
- Mechanics: continuum plasticity, linear elastic and elastic-plastic fracture parameters.

2. Broad and profound scientific and technical knowledge of Materials Engineering and Applications and the skills to use this knowledge effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and relations to other fields, and reaching in numerous instances the forefront of scientific or industrial research and development. The knowledge is the basis for innovative contributions to the discipline in the form of new knowledge on materials or materials-driven development of new designs:
- structure of metals, polymers & ceramics: microstructure; structure formation and transformation; defects from the atomic to the macroscopic level.

• material properties and their effects on designs: mechanical properties (strength, fracture toughness, fatigue, environment-assisted cracking); functional properties (electrical, thermal and magnetic); durability (corrosion and degradation).
• material production: solidification (casting); deformation (extrusion, rolling, forging, forming); welding.
• material-related design aspects: materials at high temperatures (corrosion, creep, (thermo-mechanical) fatigue); materials exposed to hydrogen; materials for solar cells; self-healing material.
3. Thorough knowledge of paradigms, methods and tools as well as the skills to actively apply this knowledge for analysing, modelling, simulating, designing and performing re-search with respect to materials-related aspects in mechanical engineering design.
• knowledge of and experience with techniques for structure characterisation.
• knowledge of and experience with techniques for property determination.
• knowledge of and experience with methods in computational materials science.
• knowledge of experimental techniques; experience with devising experimental set-ups and with conducting experiments; interpretation of experimental results taking experimental artefacts into account.
4. Capability to independently solve technological problems in a systematic way involving problem analysis, formulating sub-problems and providing innovative technical solutions, also in new and unfamiliar situations. This includes a professional attitude towards identifying and acquiring lacking expertise, monitoring and critically evaluating existing knowledge, planning and executing research, adapting to changing circumstances, and integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.
• systematic analysis of material properties and of materials-related design aspects; interpretation of the analysis results.
• put forward methods for improvement of materials properties in relation with the design, such as the selection of alternative compositions, processing conditions and treatments of the material (thermal cycles, deformation sequence, surface treatment, welding conditions, etc.).
• put forward alternative and innovative solutions to materials-related design problems by selection for a specific application of alternative materials, material treatments or conditions the materials are subjected to.
• research into the technological, economical and societal feasibility of proposed methods and solutions.
• elaboration of the proposed methods and solutions to such an extent that implementation can take place.
5. Capability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.
• work independently and in teams on problems of high technological and/or scientific complexity.
• the skills to set up and maintain a plan, to delegate and to coordinate tasks, to negotiate and handle conflicts, to recognise strong and weak points of themselves and of others.
• handle tasks which initially seem straightforward, but at a later stage require additional knowledge.
6. Capability to effectively communicate (including presenting and reporting) about one's work such as solutions to problems, conclusions, knowledge and considerations, to both professionals and non-specialised public in the English language.
• give well-structured presentations for different audiences using state-of-the-art presentation techniques.
• write well-structured and clear reports and contributions to scientific papers.

• convey acquired knowledge and results to others in a clear and convincing way.
• read, interpret and summarise literature; idem for verbal communication.

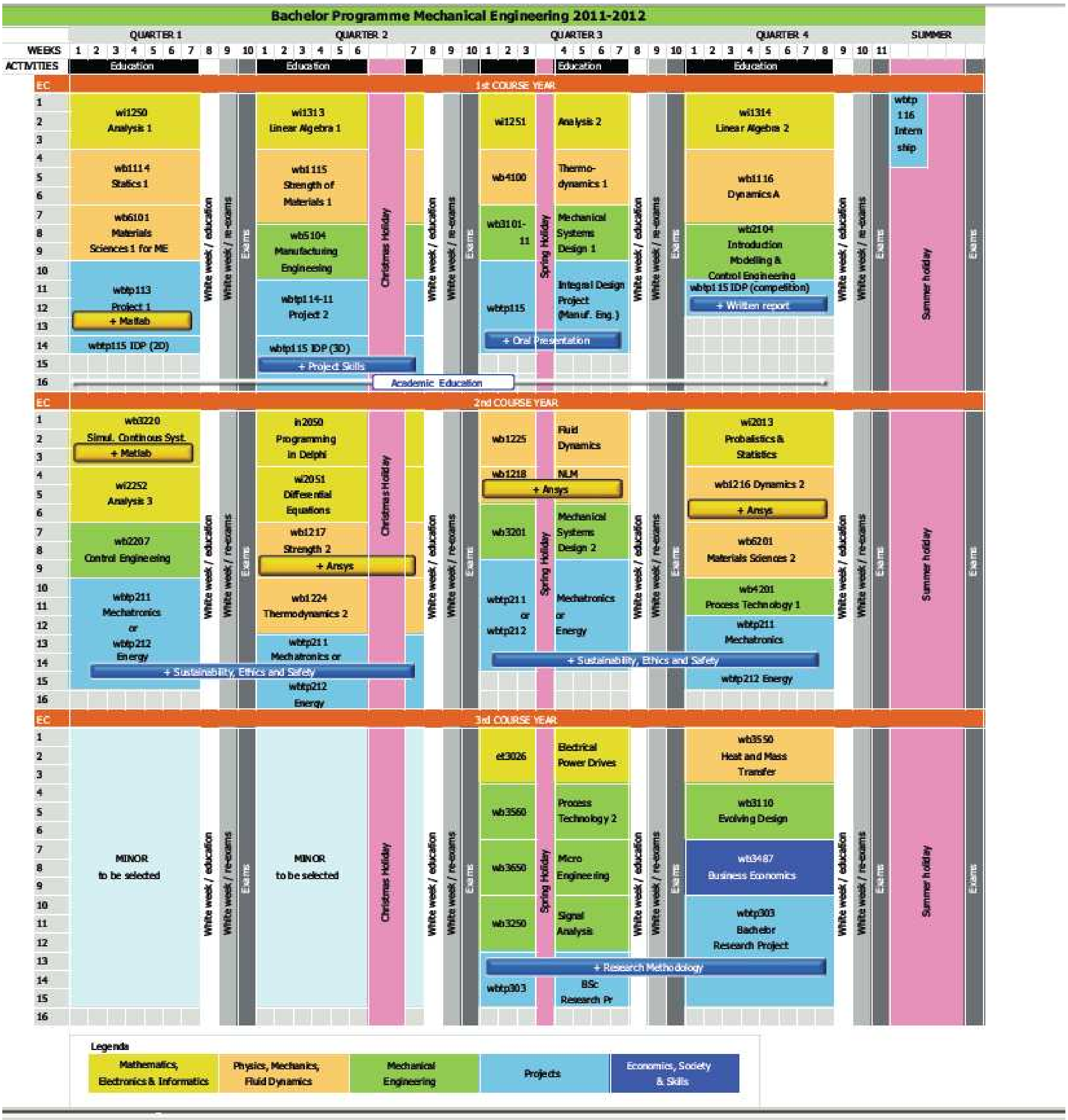
7. Capability to evaluate and assess the technological, ethical and societal impact of one's work, and to take responsibility with regard to sustainability, economy and social well-being.

- describe and implement sustainable development.
- recognise moral issues, argue who play a role in these and be aware of his / her own position.
- assess safety risks both qualitatively and quantitatively; methods for reducing safety risks.
- assess the economic feasibility of technical solutions.

8. Attitude to independently maintain professional competence through life-long learning.

- awareness of the (historic) development of the discipline, of its technological and scientific boundaries, and consequently of the necessity of life-long learning to maintain the desired level.

Appendix 4: Overview of the curricula



Program overview

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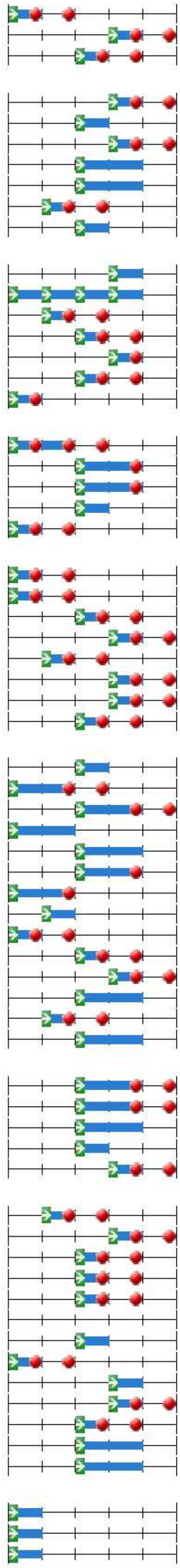
Year	**2012/2013**
Organization	**Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen**
Education	**Master Mechanical Engineering**

Code	Omschrijving	ECTS	p1 | p2 | p3 | p4 | p5
Master ME 2012	**Master Mechanical Engineering 2012**		
ME variant Transportation Engineering (ME-TE)	**ME Track Transportation Engineering (ME-TE)**		
Obligatory Courses ME-TE			
ME1402	Attending Student Colloquia	1	
ME1405	Automation of Transport Systems	3	
ME1406	Control of Intelligent Transport Infrastructures	3	
WB3420-11	Introduction Transport and Logistic Engineering	6	
Specialisation Transport Engineering & Logistics (incl. Production Engineering & Logistics) (ME-TE-TEL)			
Obligatory Courses ME-TE-TEL			
ME1407	Masterclass Transport Engineering & Logistics	3	
ME1410-12	Quantitative Methods for Logistics	6	
ME1410-12 D1	*Introduction to Quantitative Methods for Logistics*	*3*	
ME1410-12 D2	*Quantitative Methods for Logistics*	*3*	
WB3416-03	Design with the Finite Element Method	3	
WB3417-04	Discrete Systems: MPSC	5	
WB3419-03	Characterization and Handling of Bulk Solid Materials	6	
WB3422-11	Design of Transport Equipment	6	
WB3423-04	The Delft Systems Approach	3	
Recommended Elective Courses ME-TE-TEL			
SC4081-10	Knowledge Based Control Systems	4	
Specialisation Mechanical Systems and Integration (ME-TE-MSI)			
Obligatory Courses ME-TE-MSI			
MT213	Marine Engineering C	2	
MT219-09	Marine Engineering 1	4	
MT219-09 D1	*Marine Engineering 1 - Exam*	*4*	
MT219-09 D2	*Marine Engineering 1*	*0*	
MT527	Hydro Mechanics 3	2	
MT527 D1	*Hydro Mechanics 3 exam*	*1,5*	
MT527 D2	*Hydro Mechanics 3, practical*	*0,5*	
WB4408A	Diesel Engines A	4	
WB4408B	Diesel Engines B	4	
Master year 2 TEL			
ME2110-10	Literature Assignment	10	
ME2130-15	Research Assignment	15	
ME2190-35	MSc Project	35	
Master year 2 MSI			
ME2130-15	Research Assignment	15	
ME2190-45	MSc Project MSI & DE	45	
ME Track Control Engineering (ME-CE)			
Obligatory Courses ME-CE			
ME1200	Robust and Multivariable Control Design	6	
SC4010	Introduction Project SC	3	
SC4025	Control Theory	6	
SC4050	Integration Project SC	5	
SC4092	Modelling and Nonlinear Systems Theory	4	
SC4110	System Identification	5	
WB2305	Digital Control	3	
Elective Courses Mechanical Systems ME-CE			
WB1406-07	Experimental Dynamics	3	
WB1413-04	Multibody Dynamics B	4	
WB1418-07	Engineering Dynamics	4	
WB1440	Eng. Optimization: Concept & Applications	3	
WB2303-10	Measurement in Engineering	3	
WB2414-09	Mechatronic System Design	4	
WB2428-03	Mechanical Design in Mechatronics	5	
WB3404A	Vehicle Dynamics A	3	
Elective Courses Processes ME-CE			
SC4060	Model Predictive Control	4	
WB1427-03	Advanced Fluid Dynamics A	5	

WB4302	Thermodynamic Aspects of Energy Conversion	4
WB4422-11	Thermal Power Plants	6
WB4431-05	Modeling of Process and Energy Systems	4
Elective Courses Automotive ME-CE		
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
SC4210	Vehicle Mechatronics	4
SC4230TU	Vehicle Dynamics B - Antilock Braking Systems	3
WB1406-07	Experimental Dynamics	3
WB1413-04	Multibody Dynamics B	4
WB2404	Man-machine systems	4
WB3404A	Vehicle Dynamics A	3
Elective Courses Robotics ME-CE		
ME1120	Space Robotics	4
ME1130	Robotics Practicals	3
ME1140	3D Robot Vision	3
ME1150	Probabilistic Robotics	3
SC1200	Modern Robotics	5
SC4240TU	Control Methods for Robotics	3
WB2433-03	Humanoid Robots	3
Elective Courses Wind Energy ME-CE		
AE3W02TU	Introduction to Wind Energy	4
AE4W09	Wind Turbine Design	5
AE4W11	Exercise Wind Turbine Design	1
OE5662	Offshore Wind Farm Design	4
WB1418-07	Engineering Dynamics	4
Elective Courses Transportation Networks ME-CE		
CIE4801	Transportation and Spatial Modelling	6
CIE4811-09	Design and Control of Public Transport Systems	6
CIE4821-09	Traffic Flow Theory and Simulation	6
CIE4822-09	Traffic Management and Control	6
CIE5803-09	Railway Traffic Management	4
CIE5804-09	Innovations in Dynamic Traffic Management	4
ME1406	Control of Intelligent Transport Infrastructures	3
WI4062TU	Transport, Routing and Scheduling	3
Elective Courses Smart Physical Systems ME-CE		
AE4X09	Sensor and Smart Materials	3
AP3121 D	Imaging Systems	6
AP3231TU D	Medical Imaging	6
AP3381	Theoretical Optics	6
AP3391	Geometrical Optics	6
AP3401	Introduction to Charged Particle Optics	6
ET4283	Advanced Digital Image Processing	6
ET4390	Imaging Sensors	5
ME1611-10	Physics for Mechanical Engineers	4
ME1612-10	Intro to Nanoscience and Technology	3
SC4045	Control for High Resolution Imaging	3
UL-SMO	Single Molecule Optics	6
WB2414-09	Mechatronic System Design	4
WI2604	Numerical Methods 1	6
Elective Courses Systems Biology ME-CE		
AP3161 D	Cellular Dynamics: Stochasticity and Signalling	6
AP3691 D	Evolution and Engineering of Living Systems	6
IN4176	Functional Genomics and Systems Biology	6
LM3512TU	Systems Biology	3
SC4250	Probabilistic Models in the Life Sciences	2
Elective Courses Fundamentals ME-CE		
SC4040	Filtering & Identification	6
SC4045	Control for High Resolution Imaging	3
SC4060	Model Predictive Control	4
SC4081-10	Knowledge Based Control Systems	4
SC4081-10 D1	*Knowledge Based Control Systems, Exam*	*3*
SC4081-10 D2	*Knowledge Based Control Systems, Literature*	*0,5*
SC4081-10 D3	*Knowledge Based Control Systems, Matlab*	*0,5*
SC4091	Optimization in Systems and Control	4
SC4120	Special Topics in Signals, Systems & Control	3
SC4160	Modeling and Control of Hybrid Systems	3
SC4240TU	Control Methods for Robotics	3
WI4218	Convex Optimization and Systems Theory	6
WI4221	Control of Discrete-Time Stochastic Systems	6
Master year 2		
ME2200-15	Traineeship (optional)	15
ME2210-15	Literature Assignment	15
ME2290-45	MSc Thesis Project	45
ME Track Sustainable Processes and Energy Technologies (ME-SPET)		
Obligatory Courses ME-SPET		



WB1427-03	Advanced Fluid Dynamics A	5
WB4300B	Fundamentals of Fluid Machinery	2
WB4400-03	Introduction to Sustainable Process and Energy Technologies	1
WB4431-05	Modeling of Process and Energy Systems	4
WB4435-05	Equipment for Heat Transfer	3
WB4436-05	Equipment for Mass Transfer	3
WB4438-11	Technology and Sustainability	6
Specialisation Energy Technology (ME-SPET-ET)		
WB4422-11	Thermal Power Plants	6
At least 2 courses from:		
WB1428-3	Computational Fluid Dynamics	3
WB4302	Thermodynamic Aspects of Energy Conversion	4
WB4410A	Refrigeration Fundamentals	3
WB4420	Gas Turbines	3
Recommended Elective Courses ME-SPET-ET		
AE4140	Gas Dynamics I	3
ME1520	Non-Equilibrium Thermodynamics for Engineers	4
SET3041	Energy from Biomass	4
WB1424ATU	Turbulence A	6
WB1424BTU	Race Car Aerodynamics	3
WB1429-03	Microfluidics	3
WB4402	Project Engineering	6
WB4403-12	Advanced Reaction & Separation Systems	6
WB4421	Gas Turbine Simulation/Application	3
WB4425-09TU	Fuel Cell Systems	3
WB4426	Indoor Climate Control Fundamentals	3
WB4427	Refrigeration Technology and Applications	4
WB4429-03	Thermodynamics of Mixtures	3
WI4019	Non-linear Differential Equations	6
WM0605TU	Business Economics for Engineers	4
Specialisation Process Technology (ME-SPET-PT)		
WB4433-11	Process Plant Design	6
At least 2 courses from:		
WB1428-3	Computational Fluid Dynamics	3
WB4403-12	Advanced Reaction & Separation Systems	6
WB4429-03	Thermodynamics of Mixtures	3
Recommended Elective Courses ME-SPET-PT		
CH3141	Molecular Thermodynamics	6
CH3671	Molecular Simulation	6
ME1520	Non-Equilibrium Thermodynamics for Engineers	4
ME1592CH	Process Intensification	6
WB1424ATU	Turbulence A	6
WB1424BTU	Race Car Aerodynamics	3
WB1429-03	Microfluidics	3
WB4302	Thermodynamic Aspects of Energy Conversion	4
WB4402	Project Engineering	6
WB4410A	Refrigeration Fundamentals	3
WB4420	Gas Turbines	3
WI4019	Non-linear Differential Equations	6
WM0605TU	Business Economics for Engineers	4
Annotation Technology in Sustainable Development (ME-SPET-ATSD)	**Specialisation Annotation Technology in Sustainable Development (ME-SPET-ATSD)**	
Recommended Elective Courses ME-SPET-ATSD		
ME1520	Non-Equilibrium Thermodynamics for Engineers	4
Recommended Elective Courses Cluster A ME-SPET-ATSD		
AE3W02TU	Introduction to Wind Energy	4
AP3141 D	Environmental Physics	6
Recommended Elective Courses Cluster B ME-SPET-MPS		
WM0801TU	Introduction to Safety Science	3
WM0903TU	Technology and Global Development	4
Master year 2		
ME2300-15	Internship	15
ME2390-45	Final Project including a literature study report	45
ME Track Precision and Microsystems Engineering (ME-PME)		
Obligatory Courses ME-PME		
ME1611-10	Physics for Mechanical Engineers	4
ME1640	Micro- & Nanosystems Design & Fabrication, incl. MEMS Lab.	4
SC4026	Control System Design	3
WB1440	Eng. Optimization: Concept & Applications	3
WB1450-05	Mechanical Analysis for Engineering	4
WB2303-10	Measurement in Engineering	3
WB2414-09	Mechatronic System Design	4
WB5451-05	Attending Student Colloquia	1

WB5452-10	Intro lab PME (new style)	3
Specialisation Engineering Mechanics (ME-PME-EM)		
Obligatory Courses ME-PME-EM		
WB1406-07	Experimental Dynamics	3
WB1418-07	Engineering Dynamics	4
WB1451-05	Engineering Mechanics Fundamentals	4
Recommended Elective Courses ME-PME-EM		
AE4117	Fluid-Structure Interaction	4
AE4684	Fibre Reinforced Materials in Aerospace Structures	3
AE4930	Aeroelasticity	3
AE4X04	Materials Selection in Mechanical Design	3
CIE5142	Computational Methods in Non-Linear Solid Mechanic	3
CIE5145	Random Vibrations	4
IN4073	Embedded Real-Time Systems	6
ME1612-10	Intro to Nanoscience and Technology	3
MS3021	Metals Science	4
MS4015	Mechanical Behaviour of Materials	4
SC4110	System Identification	5
WB1310	Multibody Dynamics A	3
WB1405A	Stability of Thin-Walled Structures 1	4
WB1412	Linear & Non-lineair Vibrations in Mechanical Systems	3
WB1413-04	Multibody Dynamics B	4
WB1416-11	Numerical Methods for Dynamics	4
WB1428-3	Computational Fluid Dynamics	3
WB1441	Engineering Optimization 2	3
WB1443	Matlab in Engineering Mechanics	2
WB2454-07	Multiphysics Modelling using COMSOL	4
WB3404A	Vehicle Dynamics A	3
WI4014TU	Numerical Analysis	6
WI4201	Scientific Computing	6
WM1102TU	Written English for Technologists-2	3
Specialisation Mechatronic System Design (ME-PME-MSD)		
Obligatory Courses ME-PME-MSD		
WB1418-07	Engineering Dynamics	4
WB2427	Predictive Modelling	3
WB2428-03	Mechanical Design in Mechatronics	5
WB5400-08	Mechatronic System Design 2	4
Recommended Elective Courses ME-PME-MSD		
ET4117	Electrical Machines and Drives	4
ME1200	Robust and Multivariable Control Design	6
ME1612-10	Intro to Nanoscience and Technology	3
ME1650	Masterclass Advanced Motion Systems	2
SC4092	Modelling and Nonlinear Systems Theory	4
SC4110	System Identification	5
TN2053(-10)	Elektromagnetism	6
WB1413-04	Multibody Dynamics B	4
WB1416-11	Numerical Methods for Dynamics	4
WB1441	Engineering Optimization 2	3
WB1443	Matlab in Engineering Mechanics	2
WB2305	Digital Control	3
WB2454-07	Multiphysics Modelling using COMSOL	4
WB3404A	Vehicle Dynamics A	3
Specialisation Micro and Nano Enigineering (ME-PME-MNE)		
Obligatory Courses ME-PME-MNE		
ME1612-10	Intro to Nanoscience and Technology	3
ME1613-09	Operations Management for Microsystems Production	3
ME1615	Micro-Assembly, Packaging and Test	3
WB2427	Predictive Modelling	3
Recommended Elective Courses ME-PME-MNE		
4052CHNANY	Chemical Nanotechnology (CNT)	6
AE4X04	Materials Selection in Mechanical Design	3
CH2071TU	Polymer Science	4
ET4117	Electrical Machines and Drives	4
ET4248	Introduction to Microelectronics	3
ET4257	Sensor and Actuators	4
ET4260	Microsystem Integration	4
ET4289	Integrated Circuits and MEMS Technology	4
ET4390	Imaging Sensors	5
ET8017	Electronic Instrumentation	5
IN4073	Embedded Real-Time Systems	6
MS3432	Determination of Microstructure	4
SC4070	Control Systems Lab	4
SC4092	Modelling and Nonlinear Systems Theory	4
WB1406-07	Experimental Dynamics	3
WB1418-07	Engineering Dynamics	4

WB1429-03	Microfluidics	3
WB1443	Matlab in Engineering Mechanics	2
WB1451-05	Engineering Mechanics Fundamentals	4
WB2428-03	Mechanical Design in Mechatronics	5
WB2454-07	Multiphysics Modelling using COMSOL	4
WB3423-04	The Delft Systems Approach	3
WB3424-08	Production Organisation Principles	3
WB5400-08	Mechatronic System Design 2	4
WM0516TU	Turning Technology into Business	6
WM0605TU	Business Economics for Engineers	4
WM1102TU	Written English for Technologists-2	3

Specialisation Automotive (ME-PME-AUT)

Obligatory Courses ME-PME-AUT

ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
SC4210	Vehicle Mechatronics	4
WB3404A	Vehicle Dynamics A	3

Recommended Elective Courses ME-PME-AUT

BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
ET4117	Electrical Machines and Drives	4
ID5242	Automotive Design	6
ME1612-10	Intro to Nanoscience and Technology	3
MT216	Introduction Combustion Engines	3
SC4040	Filtering & Identification	6
SC4070	Control Systems Lab	4
SC4091	Optimization in Systems and Control	4
SC4092	Modelling and Nonlinear Systems Theory	4
SC4110	System Identification	5
SC4230TU	Vehicle Dynamics B - Antilock Braking Systems	3
WB1406-07	Experimental Dynamics	3
WB1413-04	Multibody Dynamics B	4
WB1418-07	Engineering Dynamics	4
WB1451-05	Engineering Mechanics Fundamentals	4
WB2404	Man-machine systems	4
WBP202	Haptic System Design	4
WM0808TU	Safety in Transportation	5

Master year 2

Or:

ME2400-15	Industrial Traineeship	15
ME2420-10	First Student Project	10
ME2490-35	Final Student Project (Thesis)	35

Or:

ME2400-15	Industrial Traineeship	15
ME2490-45	First Project + Thesis Project combined	45

Or:

ME2420-10	First Student Project	10
ME2490-50	Traineeship + Thesis Project combined	50

Or:

ME2490-60	First Project + Traineeship + Thesis Project combined	60

ME Track Biomechanical Design (ME-BMD)

Obligatory Courses ME-BMD

BM1104	Experimental design, statistics & the human	3
SC4026	Control System Design	3
WB1413-04	Multibody Dynamics B	4
WB2306	The Human Controller	3
WB2404	Man-machine systems	4

Specialisation BioRobotics (ME-BMD-BR)

Obligatory Courses ME-BMD-BR

BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
SC4070	Control Systems Lab	4
SC4240TU	Control Methods for Robotics	3
WB2433-03	Humanoid Robots	3

Recommended Elective Courses ME-BMD-BR

BM1020L	M1822W Zenuwstelsel	5
BM1210	Medical Instruments A: Clinical Challenges and Engineering Solutions	3
ET4283	Advanced Digital Image Processing	6
IN4010(-12)	Artificial Intelligence Techniques	6
IN4073	Embedded Real-Time Systems	6
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
ME1105	Human and Robot Locomotion	3
ME1110	Medical Device Prototyping	6
ME1120	Space Robotics	4
ME1130	Robotics Practicals	3

ME1140	3D Robot Vision	3
ME1150	Probabilistic Robotics	3
ME1160	Compliant Mechanisms	4
SC4060	Model Predictive Control	4
SC4081-10	Knowledge Based Control Systems	4
SC4081-10 D1	*Knowledge Based Control Systems, Exam*	*3*
SC4081-10 D2	*Knowledge Based Control Systems, Literature*	*0,5*
SC4081-10 D3	*Knowledge Based Control Systems, Matlab*	*0,5*
SC4091	Optimization in Systems and Control	4
SC4110	System Identification	5
SC4120	Special Topics in Signals, Systems & Control	3
TI3084TU	Programming with C++	3
WB1406-07	Experimental Dynamics	3
WB1416-11	Numerical Methods for Dynamics	4
WB1418-07	Engineering Dynamics	4
WB1440	Eng. Optimization: Concept & Applications	3
WB2301-5	System Identification and Parameter Estimation	7
WB2303-10	Measurement in Engineering	3
WB2305	Digital Control	3
WB2308	Biomedical Engineering Design	4
WB2414-09	Mechatronic System Design	4
WB2427	Predictive Modelling	3
WB2428-03	Mechanical Design in Mechatronics	5
WB2432	Bio Mechatronics	4
WB2436-12	Bio Inspired Design	4
WB3417-04	Discrete Systems: MPSC	5
WBP202	Haptic System Design	4
Specialisation BioInspired Technology (ME-BMD-BITE)		
Obligatory Courses ME-BMD-BITE		
WB2308	Biomedical Engineering Design	4
WB2428-03	Mechanical Design in Mechatronics	5
WB2433-03	Humanoid Robots	3
WB2436-12	Bio Inspired Design	4
Recommended Elective Courses ME-BMD-BITE		
AP3461	The Origins of Life	6
AP3691 D	Evolution and Engineering of Living Systems	6
BM1210	Medical Instruments A: Clinical Challenges and Engineering Solutions	3
BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
CIE5251-09	Structural Design, Special Structures	5
LM3512TU	Systems Biology	3
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
ME1110	Medical Device Prototyping	6
ME1120	Space Robotics	4
ME1160	Compliant Mechanisms	4
SC4060	Model Predictive Control	4
SC4091	Optimization in Systems and Control	4
SC4110	System Identification	5
SC4120	Special Topics in Signals, Systems & Control	3
SC4250	Probabilistic Models in the Life Sciences	2
WB1310	Multibody Dynamics A	3
WB1406-07	Experimental Dynamics	3
WB1413-04	Multibody Dynamics B	4
WB1416-11	Numerical Methods for Dynamics	4
WB1418-07	Engineering Dynamics	4
WB1429-03	Microfluidics	3
WB1440	Eng. Optimization: Concept & Applications	3
WB2301-5	System Identification and Parameter Estimation	7
WB2303-10	Measurement in Engineering	3
WB2305	Digital Control	3
WB2408	Physiological Systems	3
WB2414-09	Mechatronic System Design	4
WB2427	Predictive Modelling	3
WB2432	Bio Mechatronics	4
WBP202	Haptic System Design	4
Specialisation Automotive Human Factors (ME-BMD-AUT)		
Obligatory Courses ME-BMD-AUT		
BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
SC4210	Vehicle Mechatronics	4
WB3404A	Vehicle Dynamics A	3
Recommended Elective Courses ME-BMD-AUT		
AE4307	Flight and Space Simulation	4
CIE4801	Transportation and Spatial Modelling	6
		6

CIE4821-09	Traffic Flow Theory and Simulation	
CIE5805	Intelligent Vehicles	4
ID5242	Automotive Design	6
ME1120	Space Robotics	4
MT216	Introduction Combustion Engines	3
SC4070	Control Systems Lab	4
SC4091	Optimization in Systems and Control	4
SC4230TU	Vehicle Dynamics B - Antilock Braking Systems	3
WB1406-07	Experimental Dynamics	3
WB1413-04	Multibody Dynamics B	4
WB2301-5	System Identification and Parameter Estimation	7
WB2303-10	Measurement in Engineering	3
WB2414-09	Mechatronic System Design	4
WBP202	Haptic System Design	4
WM0808TU	Safety in Transportation	5

Specialisation Haptic Interfaces (ME-BMD-HI)

Obligatory Courses ME-BMD-HI

BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
WB2301-5	System Identification and Parameter Estimation	7
WBP202	Haptic System Design	4

Recommended Elective Courses ME-BMD-HI

IN4010(-12)	Artificial Intelligence Techniques	6
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3
ME1120	Space Robotics	4
SC4060	Model Predictive Control	4
SC4070	Control Systems Lab	4
SC4081-10	Knowledge Based Control Systems	4
SC4081-10 D1	*Knowledge Based Control Systems, Exam*	*3*
SC4081-10 D2	*Knowledge Based Control Systems, Literature*	*0,5*
SC4081-10 D3	*Knowledge Based Control Systems, Matlab*	*0,5*
SC4091	Optimization in Systems and Control	4
SC4110	System Identification	5
SC4120	Special Topics in Signals, Systems & Control	3
WB1418-07	Engineering Dynamics	4
WB1440	Eng. Optimization: Concept & Applications	3
WB2303-10	Measurement in Engineering	3
WB2305	Digital Control	3
WB2308	Biomedical Engineering Design	4
WB2414-09	Mechatronic System Design	4
WB2427	Predictive Modelling	3
WB2428-03	Mechanical Design in Mechatronics	5
WB2432	Bio Mechatronics	4
WB2436-12	Bio Inspired Design	4
WB3417-04	Discrete Systems: MPSC	5

Specialisation Sports Engineering (ME-BMD-SE)

Obligatory Courses ME-BMD-SE

BM1240	Human Movement Control A: Musculoskeletal Mechanics	3
BM1250	Human Movement Control B Neuromuscular Control	3
ME1170	Special Topics in Sports Engineering	3
ME1610-11	Tissue Biomechanics of Bone, Cartilage and Tendon	3
WB2432	Bio Mechatronics	4

Recommended Elective Courses ME-BMD-SE in VU (minimum 6 EC, maximum 12 EC)

VU-code's, available as soon as possible

Recommended Elective Courses ME-BMD-SE

BM1100	Orthopaedic Implants and Technology	3
BM1200	Computational Mechanics of Tissues and Cells	6
BM1230	Selected Topics in Tissue Biomechanics and Implants	2
ET4363	Medical Technology I (Diagnostic Devices) & Health Care Systems	5
ME1105	Human and Robot Locomotion	3
WB1424BTU	Race Car Aerodynamics	3
WB2301-5	System Identification and Parameter Estimation	7
WB2303-10	Measurement in Engineering	3
WB2308	Biomedical Engineering Design	4
WB2408	Physiological Systems	3
WB2414-09	Mechatronic System Design	4
WB2436-12	Bio Inspired Design	4
WBP202	Haptic System Design	4

Master year 2 Assignments, Projects, Thesis

ME2500-15	Traineeship	15
ME2510-3	Literature Colloquium	3
ME2510-7	Literature Report	7
ME2590-32	MSc Project	32
ME2591-3	Introductory Colloquium	3

ME Track Solid and Fluid Mechanics (ME-SFM)		
Obligatory Courses ME-SFM		
AE4117	Fluid-Structure Interaction	4
WB1427-03	Advanced Fluid Dynamics A	5
WB1428-3	Computational Fluid Dynamics	3
WB1451-05	Engineering Mechanics Fundamentals	4
WI3105ME	Analysis 4	3
WI4014TU	Numerical Analysis	6
Choose 1 Course from:		
CIE5142	Computational Methods in Non-Linear Solid Mechanic	3
Choose 6 EC from:		
MOT1460	Corporate Finance	4
WM0320TU	Ethics and Engineering	3
WM0605TU	Business Economics for Engineers	4
WM0801TU	Introduction to Safety Science	3
WM0903TU	Technology and Global Development	4
maximum 1 language course		
Specialisation Fluid Mechanics (ME-SFM-FM)		
Obligatory Courses ME-SFM-FM		
WB1424ATU	Turbulence A	6
Choose at least 3 courses from:		
AE4140	Gas Dynamics I	3
AP3181 D	Applied Multiphase Flow	6
WB1424BTU	Race Car Aerodynamics	3
WB1429-03	Microfluidics	3
WB5500	Biological Fluid Mechanics	3
Specialisation Engineering Dynamics (ME-SFM-ED)		
Obligatory Courses ME-SFM-ED		
WB1418-07	Engineering Dynamics	4
Choose at least 2 courses from:		
WB1406-07	Experimental Dynamics	3
WB1412	Linear & Non-lineair Vibrations in Mechanical Systems	3
WB1413-04	Multibody Dynamics B	4
Specialisation Structural Optimisation and Computer Mechanics (ME-SFM-SOCM)		
Obligatory Courses ME-SFM-SOCM		
WB1440	Eng. Optimization: Concept & Applications	3
Choose at least 2 courses from:		
WB1405A	Stability of Thin-Walled Structures 1	4
WB1441	Engineering Optimization 2	3
Recommended Elective Courses ME-SFM		
AE4120	Viscous Flows	3
AE4141	Gas Dynamics II	3
AE4180	Flow Measurement Techniques	3
AE4900TU	Continuum Mechanics	4
CIE5145	Random Vibrations	4
WB1310	Multibody Dynamics A	3
WB1416-11	Numerical Methods for Dynamics	4
WB2303-10	Measurement in Engineering	3
WB2414-09	Mechatronic System Design	4
WI4006	Special Functions	6
WI4011	Computational Fluid Dynamics	6
WI4141TU	Matlab for Advanced Users	3
WI4150TU	Partial Differential Equations 2	3
Other courses on request		
Master Year 2		
ME2600-15	Internship	15
ME2690-45	MSc Thesis, including literature-study report	45
ME Track Materials Engineering and Applications (ME-MEA)		
Obligatory Courses ME-MEA		
ME1301	Societys Needs: Case Studies and Materials Challenges	4
ME1302	Structure and Properties of Materials	8
ME1303	Materials for Light-Weight Constructions	5
ME1304	Lab Classes	4
WM0320TU	Ethics and Engineering	3
Specialised Courses ME-MEA; Obligatory		
ME1305	Materials for Highly Loaded Structures	5
ME1306	Materials at High Temperature	5
ME1307	Materials for Measurement and Control Devices	5
MS4015	Mechanical Behaviour of Materials	4
Choose One Course From:		
AE4X10	Self Healing Materials	3
ME1308	Materials for Hydrogen and Solar Applications	4
		4

ME1309	Advanced Research Methods	
Recommended Electives Courses ME-MEA		
CIE4100	Materials and Ecological Engineering	4
CIE5100	Repair and Maintenance of Construction Materials	4
CIE5102	Forensic Building Materials Engineering	3
CIE5110	Concrete - Science and Technology	4
CIE5142	Computational Methods in Non-Linear Solid Mechanic	3
CIE5146	Micromechanics and Computational Modelling of Buildingmaterial	3
ET4376	Photovoltaic Basics	4
MS3401	Primary Metals Production	3
MS3421	Developments in Production and Processing	2
MS3432	Determination of Microstructure	4
MS4071	Materials in Art and Design	3
MS4111	Thin Film Materials	3
WB1451-05	Engineering Mechanics Fundamentals	4
WB2303-10	Measurement in Engineering	3
WB4422-11	Thermal Power Plants	6
WB4438-11	Technology and Sustainability	6
WI4014TU	Numerical Analysis	6
WI4141TU	Matlab for Advanced Users	3
Assignments, Projects, Thesis ME-MEA		
ME2350	Traineeship MEA	15
ME2360	Master Project MEA	45
Annotation Entrepreneurship		

Appendix 5: Quantitative data regarding the programmes

Data on intake, transfers and graduates

Table 1 Intake and drop-out of VWO freshmen in the Bachelor's programme (1 October 2011)

Cohort	VWO freshmen	Re-enrolled after 1st year	Drop-out in the 1st year	
	# students	# students	# students	Percentage
2002	94	70	24	26%
2003	211	171	40	19%
2004	242	191	51	21%
2005	275	207	68	25%
2006	253	200	53	21%
2007	281	225	56	20%
2008	326	265	61	19%
2009	363	230	133	37%

Table 2 propaedeutic yield per cohort of 'VWO freshmen' (1 October 2011)

Cohort	Cohort size	Cumulative propaedeutic yield within n years						Still enrolled	Total drop-out	Maximum attainable yield
		<=1	<=2	<=3	<=4	<=5	>5			
2002	**94**	19%	36%	43%	52%	54%	59%	1%	40%	60%
2003	**211**	20%	37%	53%	59%	61%	65%	2%	33%	67%
2004	**242**	12%	45%	51%	55%	60%	63%	1%	36%	64%
2005	**275**	16%	27%	45%	53%	58%	62%	3%	35%	65%
2006	**253**	0%	31%	48%	56%	60%		11%	29%	71%
2007	**281**	12%	31%	48%	56%			15%	29%	71%
2008	**326**	16%	30%	42%				28%	29%	71%
2009	**363**	10%	21%					38%	40%	60%
2010	**341**	15%						58%	28%	72%

Table 3 Bachelor yield per cohort of 'VWO freshmen' who re-enrolled after their first year. (VSNU)

cohort	cohort size	cumulative Bachelor yield within n years				
		<= 3	**<= 4**	**<= 5**	**<= 6**	**> 6**
2002	71	11%	25%	37%	51%	66%
2003	182	3%	18%	38%	56%	65%
2004	200	4%	19%	39%	56%	
2005	218	5%	19%	34%		
2006	210	8%	20%			
2007	242	9%				
2008	285					
2009	257					

It is not possible to give a reliable overview of the intake of Master's students in the programme. For graduates from the 3mE's Bachelor's programme it is often difficult to determine when they commenced the Master's programme. A lot of them participate in master's courses (long) before they have passed their bachelor's graduation. The Bachelor-before-Master rule (Harde Knip) introduced in 2010 will put an end to this.

Teacher-student ratio achieved

Table 4 Student-staff ratio for the Faculty 3mE

year	number of students 3mE as per December 1st	total staff 3mE [FTE] as per December 31st	student/staff
2005	1,803	113.2	15.9
2006	1,914	126.2	15.2
2007	2,090	133.7	15.6
2008	2,308	133.3	17.3
2009	2,525	136.3	18.5
2010	2,633	137.8	19.1
2011	2,809	135.9	20.7

Average amount of face-to-face instruction per stage of the study programme

Table 5 distribution of study time in the Bachelor's programme

Course year	Lectures All students	Instructions Groups of 25 – 50 students	Project meetings Groups of 2 – 8 students	Thesis	Self study	Total study load.
	Hours	Hours	Hours	Hours	Hours	Hours
1	310	210	60	-	1100	1680
2	365	150	50	-	1115	1680
3	400	60	60	190	970	1680

Table 6 Estimated time that students spend in various forms of contact hours and self-study as a percentage of total study load (2011- 2012)

	Contact hrs			Total	Self-study and group work			Total
	Lectures, tutorials	Practical training,	Graduation Project		Individual study	Projects	Graduation Project	
Year 1	18% (300 hrs)	7% (120 hrs)	0%	**25% (420 hrs)**	45% (755 hrs)	30% (505 hrs)	0%	**75% (1260 hrs)**
Year 2	0%	2% (35 hrs)	6% (100 hrs)	**8% (135 hrs)**	0%	30% (505 hrs)	62% (1040 hrs)	**92% (1545 hrs)**
Overall	9,5% (300 hrs)	4,5% (155 hrs)	3% (100 hrs)	**17% (555 hrs)**	22% (755 hrs)	30% (1020 hrs)	31% (1040 hrs)	**83% (2780 hrs)**

Appendix 6: Programme of the site visit

time	subject	invited persons	additional info
08.45-09.00	reception of the committee	Prof. dr. T.S (Theun) Baller Prof. dr. ir. J (Hans) Hellendoorn Dr. ir. D (Dick) Nijveldt	dean director of education QA/QC staff member
9.00-10.00	management 3mE	Prof. dr. ir. J (Hans) Hellendoorn Dr. ir. S.A (Sape) Miedema F.P.M (Frans) van der Meijden L.J.H (Leonie) van den Boom Dr. ir. D (Dick) Nijveldt	director of education programme director ODE head ESAD head M&C QA/QC staff member
10.00-11.00	students BSc and MSc ME	B.M (Bart-Jan) van Roekel J.C.R (Joris) Molenaar N.J (Nils) Velders R.M.M (Romy) Welschen S (Sander) van Weperen S.F (Sander) van den Broek V (Vincent) Oldenbroek J (Johann) Dugge	*BSc 4th year* BSc 3rd year BSc 3rd year BSc 2nd year MSc-BMD MSc-PME MSc-TE MSc-SFM
11.00-11.45	lecturers BSc and MSc ME	Prof. dr. ir. J (Jerry) Westerweel Prof. dr. R (Robert) Babuska Dr. ir. S.E (Erik) Offerman Dr. R (Roelof) Koekoek Dr. ir. G.J.M (Gabrielle) Tuijthof Dr. ir. A (Anton) van Beek Prof. dr. ir. A.I (Andrzej) Stankiewicz Ir. E.J.H (Edwin) de Vries	BSc/MSc BSc/MSc BSc/MSc BSc BSc/MSc BSc/MSc BSc/MSc BSc/MSc
11.45-12.15	education committee (ME)	Prof. dr. R (Robert) Babuska Dr. ir. W (Wiebren) de Jong Ir. J.J.L (Jan) Neve Dr. ir. D.L (Dingena) Schott Dhr. P.G.J (Pieter) Smorenberg Mw. C (Carmen) Molhoek H.C (Dick) Kramers	chairman lecturer lecturer lecturer student student student
12.15-13.00	committee lunch (private)	-	
13.00-13.45	tour of the facilities (ME and MSE)	Prof. dr. ir. J (Hans) Hellendoorn F.P.M (Frans) van der Meijden Dr. ir. D (Dick) Nijveldt	director of education head ESAD QA/QC staff member
13.45-14.00	break	-	
14.00-14.30	students MSc ODE	V.H.R.I (Vincent) Doedee R.A (Robert) Weegenaar J.A (Juri) Vogel M.W (Marnix) Broer	student student student student
14.30-15.00	lecturers MSc ODE	Dr. ir. S.A (Sape) Miedema Prof. dr. ir. M.L (Mirek) Kaminski Prof. dr. ir. C (Cees) van Rhee	lecturer lecturer lecturer

		Prof. dr. ir. R.H.M (René) Huijsmans	lecturer
		A.B (Gus) Cammaert	lecturer
		Ir. J.S (Jeroen) Hoving	lecturer
		Ir. N.F.B (Niels) Diepeveen	lecturer
15.00-15.30	students MSc MSE	S.T (Shoshan) Abrahami	Int. student
		W.S (Wouter) Geertsma	Student
		W (William) Mao	Int. student
		D (Dany) Enciso	Int. student
		X (Ashley) Zhang	Int. student
		A.J (Arnold) Kolk	HBO student
		M.C.J (Maarten) van Ramshorst	Student
15.30-16.00	lecturers MSc MSE	Prof. dr. B.J (Barend) Thijsse	lecturer
		Dr. M.H.F (Marcel) Sluiter	lecturer
		Prof. dr. I.M (Ian) Richardson	lecturer
		Dr. A.J (Amarante) Böttger	lecturer
		Dr. ir. L (Lucia) Nicola	lecturer
		Dr. ir. J.M.C (Arjan) Mol	lecturer
		Dr. ir. M (Michael) Janssen	lecturer
16.00-16.30	education committee (ODE)	Prof. dr. ir. C (Cees) van Rhee	chairman
		Prof. dr. A (Andrei) Metrikine	lecturer
		V.H.R.I (Vincent) Doedee	student
		R.A (Robert) Weegenaar	student
	education committee (MSE)	Prof. dr. J (Joris) Dik	chairman
		Dr. E (Eduardo) Mendes	lecturer
		T.W (Tomas) Verhallen	student
		H (Harini) Pattabhiraman	Int. student
16.30-17.15	board of examiners 3mE	Dr. ir. C.A (Carlos) Infante Ferreira	chairman
		Dr. ir. S.A (Sape) Miedema	lecturer
		Dr. ir. R.A.J (Ron) van Ostayen	lecturer
		Dr. ir. A.J (Arjan) den Dekker	lecturer
		Prof. dr. I.M (Ian) Richardson	lecturer
		Dhr. E.P (Ewoud) van Luik	secretary
17.15-18.00	alumni 3mE	Anton Paardekooper	professional field ME-MSE-BME-S&C
		Clemens van der Nat	professional field MT-ODE
		Florian Wasser	alumnus ODE
		Sjoerd Hesdahl	alumnus ME-PME
		Tjark van Staveren	alumnus MSE
		Kevin Runge	alumnus MT-DPO
		René Hiemstra	alumnus MT-SC

time	subject	invited persons	additional info
09.00-10.00	students BSc and MSc MT	H.W (Hedde) van der Weg	BSc 2nd year
		M (Menno) Sonnema	BSc 3rd year
		A.F (Floor) Spaargaren	BSc 4th year
		D.P (Daniel) Langereis	BSc 3rd year
		R (Roel) Karstens	MSc-DPO

		A (Arno) Dubois M.J (Myriam) Koopmans	MSc-SC MSc-SC
10.00-10.45	lecturers BSc and MSc MT	Dr. ir. P (Pepijn) de Jong Ir. P (Peter) de Vos Prof. dr. ir. R.H.M (René) Huijsmans Prof. dr. ir. M.L (Mirek) Kaminski Ir. R..G (Robert) Hekkenberg Ir. J.F.J (Jeroen) Pruyn	BSc/MSc BSc/MSc BSc/MSc BSc/MSc BSc/MSc BSc/MSc
10.45-11.00	break	-	
11.00-11.30	education committee (MT)	Prof. ir. J.J (Hans) Hopman Prof. dr. ir. R.H.M (René) Huijsmans Ir. R.G (Robert) Hekkenberg Dr. ir. P (Pepijn) de Jong J.M (Jurrit) Bergsma C.W (Coen) Bouhuijs J (Koos) Meerkerk A.F (Floor) Spaargaren	chairman lecturer lecturer lecturer student student student student
11.30-12.15	tour of the facilities (MT & ODE) / individual consultations as requested in parallel	Prof. dr. ir. J (Hans) Hellendoorn F.P.M (Frans) van der Meijden Dr. ir. D (Dick) Nijveldt	director of education head ESAD QA/QC staff member
12.15-13.00	committee lunch (private)	-	
13.00-13.30	preperation for the 2nd meeting with the management	-	
13.30-14.30	2nd meeting with the management 3mE	Prof. dr. ir. J (Hans) Hellendoorn Dr. ir. S.A (Sape) Miedema F.P.M (Frans) van der Meijden L.J.H (Leonie) van den Boom Dr. ir. D (Dick) Nijveldt	director of education programme director ODE head ESAD head M&C QA/QC staff member
14.30-16.30	internal discussion session of the committee, assessment and preperation breefing session	-	
16.30-17.00	briefing session	public session	
17.00-18.00	get-together' with drinks	public session	

Appendix 7: Theses and documents studied by the committee

Prior to the site visit, the committee studied the theses of the students with the following student numbers:

Bachelor:

1369512	1359029
1509721	1358685
1518267	1365525
1221221	1363018
1369547	1269526
1371762	1369482
1364057	1320378
1547771	1362828
1159666	

Master:

1108743	1383450
1203940	1218395
1180576	1180592
1091468	1187449
1262173	1148028
1173766	1013017
1173626	1098438
9701306	1108271
1532189	1291874
1394169	1143484
1532065	1011138

During the site visit, the committee studied, among other things, the following documents (partly as hard copies and electronically distributed documents, partly via the institute's electronic learning environment):

Course materials for courses and projects:

- Course outlines
- Assignments
- Answers and assignment papers by students
- Evaluation forms

Educational committee:

- Annual educational reports
- Course evaluations

Board of Examiners

- Annual reports
- Letters and communications to staff

Professional Field Advisory Board

- Minutes

Appendix 8: Declarations of independence

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: BARBARA VAN BALEN

PRIVÉ ADRES:

KLEINE HOUTWEG 8

2012 CH HAARLEM

IS ALS ~~DESKUNDIGE~~ / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Mechanical Engineering, Materials Science and Engineering, Marine Technology, Offshore and Dredging Engineering

AANGEVRAAGD DOOR DE INSTELLING:

Technische Universiteit Delft.

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

1

nvao
nederlands - vlaamse accreditatieorganisatie

VERKLAART HIERBIJ ZODANIGE RELATIES OF BANDEN MET DE INSTELLING DE AFGELOPEN VIJF JAAR NIET GEHAD TE HEBBEN;

VERKLAART STRIKTE GEHEIMHOUDING TE BETRACHTEN VAN AL HETGEEN IN VERBAND MET DE BEOORDELING AAN HEM/HAAR BEKEND IS GEWORDEN EN WORDT, VOOR ZOVER DE OPLEIDING, DE INSTELLING OF DE NVAO HIER REDELIJKERWIJS AANSPRAAK OP KUNNEN MAKEN.

VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 28-8-2012

HANDTEKENING:

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Paul VAN HOUTTE

PRIVÉ ADRES: WIJNGAARD 23
BE - 3110 ROTSELAAR
BELGIË

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Werktuigbouwkunde 3TU OW 2012

AANGEVRAAGD DOOR DE INSTELLING:

T.U. DELFT

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

1

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Rotselaar

DATUM: 4 / 9 / 2012

HANDTEKENING:

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: JORIS DE SCHUTTER

PRIVÉ ADRES: TH. VAN RYSWYCKLAAN 1
B-2850 BOOM
BELGIE

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

WERKTUIGBOUWKUNDE

AANGEVRAAGD DOOR DE INSTELLING:

TU Delft, TU Eindhoven,
Universiteit Twente

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

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nederlands - vlaamse accreditatieorganisatie

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Boom DATUM: 2 september 2012

HANDTEKENING:

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Elze Porte

PRIVÉ ADRES:

Toekomststraat 64
7521 CT Enschede

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Werktuigbouwkunde

AANGEVRAAGD DOOR DE INSTELLING:

TU Delft

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

1

VERKLAART HIERBIJ ZODANIGE RELATIES OF BANDEN MET DE INSTELLING DE AFGELOPEN VIJF JAAR NIET GEHAD TE HEBBEN;

VERKLAART STRIKTE GEHEIMHOUDING TE BETRACHTEN VAN AL HETGEEN IN VERBAND MET DE BEOORDELING AAN HEM/HAAR BEKEND IS GEWORDEN EN WORDT, VOOR ZOVER DE OPLEIDING, DE INSTELLING OF DE NVAO HIER REDELIJKERWIJS AANSPRAAK OP KUNNEN MAKEN.

VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Rotterdam DATUM: 04-09-2012

HANDTEKENING: [signature]

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: G. Calis

PRIVÉ ADRES: Plasweg 50
3768 AN Soest

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Werktuigbouwkunde (en Maritieme Techniek)
aan TUD, TUE en UT

AANGEVRAAGD DOOR DE INSTELLING:

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

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nvao
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VERKLAART HIERBIJ ZODANIGE RELATIES OF BANDEN MET DE INSTELLING DE AFGELOPEN VIJF JAAR NIET GEHAD TE HEBBEN;

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Rotterdam DATUM: 4 sept. 2012

HANDTEKENING:

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: ir H. Grunefeld

PRIVÉ ADRES:

Wevelaan 55
3571 XS Utrecht

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

werktuigbouwkunde, maritieme techn. TUD
werktuigbouwkunde TUE

AANGEVRAAGD DOOR DE INSTELLING:

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

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nvao
nederlands - vlaamse accreditatieorganisatie

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VERKLAART STRIKTE GEHEIMHOUDING TE BETRACHTEN VAN AL HETGEEN IN VERBAND MET DE BEOORDELING AAN HEM/HAAR BEKEND IS GEWORDEN EN WORDT, VOOR ZOVER DE OPLEIDING, DE INSTELLING OF DE NVAO HIER REDELIJKERWIJS AANSPRAAK OP KUNNEN MAKEN.

VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Rotterdam

DATUM: 4 september 2012

HANDTEKENING: H. Grunefeld

2

nvao
nederlands - vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Marc Vantorre

PRIVÉ ADRES:

Drakenhoflaan 61
B 2100 Antwerpen

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Werktuigbouwkunde

AANGEVRAAGD DOOR DE INSTELLING:

TU Delft
Univ. Twente

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

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VERKLAART STRIKTE GEHEIMHOUDING TE BETRACHTEN VAN AL HETGEEN IN VERBAND MET DE BEOORDELING AAN HEM/~~HAAR~~ BEKEND IS GEWORDEN EN WORDT, VOOR ZOVER DE OPLEIDING, DE INSTELLING OF DE NVAO HIER REDELIJKERWIJS AANSPRAAK OP KUNNEN MAKEN.

VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Rotterdam

DATUM: 4/8/2012

HANDTEKENING:

2