# BIOMEDICAL ENGINEERING

FACULTY OF 3ME, MECHANICAL, MARITIME AND MATERIALS ENGINEERING

**DELFT UNIVERSITY OF TECHNOLOGY**

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# REPORT ON THE MASTER'S PROGRAMME BIOMEDICAL ENGINEERING OF DELFT UNIVERSITY OF TECHNOLOGY

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point (September 2016).

## ADMINISTRATIVE DATA REGARDING THE PROGRAMME

**Master's programme Biomedical Engineering**

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|---|---|
| Name of the programme: | Biomedical Engineering |
| CROHO number: | 66226 |
| Level of the programme: | master's |
| Orientation of the programme: | academic |
| Number of credits: | 120 EC |
| Specializations or tracks: | Track I: Musculoskeletal Biomechanics<br>Track II: Medical Devices & Bioelectronics<br>Track III: Medical Physics |
| Location(s): | Delft |
| Mode(s) of study: | full time |
| Language of instruction: | English |
| Expiration of accreditation: | 31-12-2019 |

The visit of the assessment panel Biomedical Engineering to the Faculty of 3mE of Delft University of Technology took place on 18 October 2018.

## ADMINISTRATIVE DATA REGARDING THE INSTITUTION

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

## COMPOSITION OF THE ASSESSMENT PANEL

The NVAO approved the composition of the panel on 27 August 2018. The panel that assessed the master's programme Biomedical Engineering consisted of:

- Prof. Jos Vander Sloten, KU Leuven [chair];
- Dr Inge van den Berg, University Medical Center Utrecht;
- Dr Richard Kamman, Princess Máxima Center for Pediatric Oncology;
- Pieter Wiskerke MSc, Demcon;
- Vera Koomen BSc, Eindhoven University of Technology [student member]

The panel was supported by Peter Hildering, MSc who acted as secretary. Dr. Marijn Hollstelle was second secretary during the site visit.

## WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the master's programme Biomedical Engineering at the Faculty 3ME of Delft University of Technology was part of the cluster assessment Biomedical Engineering. Between October and December 2018 the panel assessed 10 programmes at 5 universities: Vrije Universiteit

Amsterdam, Delft University of Technology, University of Groningen, Eindhoven University of Technology and University of Twente.

On behalf of the participating universities, the quality assurance agency QANU was responsible for logistical support, panel guidance and production of the reports. Peter Hildering MSc was project coordinator for QANU. Peter Hildering, MSc and Renate Prenen acted as secretaries during the site visits. Petra van den Hoorn, MSc and Dr. Marijn Hollestelle acted as second secretary during a number of the site visits.

*Panel members*
The members of the assessment panel were selected based on their expertise, availability and independence. The panel consisted of the following members:
- Prof. J. (Jos) Vander Sloten (chair)
- Dr. I.E.T. (Inge) van den Berg
- Dr. R.L. (Richard) Kamman
- Prof. J.A.E. (Jan) Eggermont
- P. (Pieter) Wiskerke, MSc
- Prof. S.C.G. (Sander) Leeuwenburgh
- Prof. R.J. (Roland) Pieters
- Prof. A.A. (Amir) Zadpoor
- Vera Koomen, BSc (student member)
- Sophie Hinterding, BSc (student member)

At each site visit, the chair, one of the student members and three regular panel members were present.

*Preparation*
On 10 September 2018, the panel chair was briefed by QANU on his role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organised on 3 October 2018. During this meeting, the panel members were instructed on the use of the assessment frameworks. The panel also discussed its working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Faculty. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to Delft University of Technology, QANU received the self-evaluation report of the programme and forwarded them to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection consisted of 15 theses and their assessment forms, based on a list of recent graduates provided. A variety of topics and tracks and examiners was included in the selection. The project coordinator and panel chair ensured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed them among all panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation report and the theses, as well as the division of tasks during the site visit.

*Site visit*
The site visit to Delft University of Technology took place on 18 October 2018. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of

the programmes: students and staff members, the programme's management, alumni, the professional field and representatives of the Board of Examiners.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

*Consistency and calibration*
In order to assure the consistency of assessment within the cluster, various measures were taken:
1. The panel composition ensured attendance of three key panel members at all site visits, including the chair;
2. The coordinator was present at the panel discussion leading to the preliminary findings at all site visits;
3. A calibration meeting took place on 17 December 2018, in which all three key panel members, including the chair and the project coordinator, discussed the assessments.

*Report*
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project coordinator sent the draft reports to the Faculty in order to have it checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty and University Board.

*Definition of judgements standards*
In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of both the standards and the programme as a whole.

**Generic quality**
The quality that, in an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

**Unsatisfactory**
The programme does not meet the generic quality standard and shows shortcomings with respect to multiple aspects of the standard.

**Satisfactory**
The programme meets the generic quality standard across its entire spectrum.

**Good**
The programme systematically surpasses the generic quality standard.

**Excellent**
The programme systematically well surpasses the generic quality standard and is regarded as an international example.

# SUMMARY JUDGEMENT

The panel establishes that the intended learning outcomes of the programme are adequate in terms of level and orientation. They are profoundly formulated and geared towards the expectations of the professional field through frequent interactions with this field. The programme has a clear profile within the field of biomedical engineering, focusing on the implementation of technological solutions. The programme's goals and aims are well-suited to achieve this goal and aims to produce competent designers as well as researchers.

The panel assesses a clear, sufficient relationship of the programme with the ILOs. The academic orientation, as well as coupling with the professional field and the acquired skill set, meet the standard. The teaching staff is very well qualified, novel didactical concepts like 'flipping the classroom' are stimulated and supported by the programme. Feedback from students is made possible by a multitude of ways. Students are heard and are very much involved in the programme, and in shaping their own studies.

The panel is positive on the changes currently being implemented in the programme to improve its coherence and feasibility, mainly the restructuring in three tracks and the introduction of a bridging programme, although it still had to be proven in practice at the time of the site visit. It advises the programme management to monitor carefully how these measures address the fit of new students within the programme and the coherence and workload of the programme. It also advises to monitor the workload of the teachers involved in each track. To increase the feasibility of the programme, the panel also advises the programme to push back the amount of time that is put in beyond the curricular time reserved for the internship and the graduation project.

The Board of Examiners is operating actively and adequately to safeguard that the assessment remains of a high level, and is aware of potential pitfalls that might arise in implementing the assessment policy. The panel highly values the assessment plan and is impressed with the achieved level of implementation of this policy amongst the teachers of the master's programme. The assessment of the final theses is considered transparent and very adequate, following the structural use of a Master Thesis Grading Rubric. Beside the rubric, some qualitative feedback would be in place, to further clarify the given score. For the internships, the panel advises a structural use of learning goals and an associated rubric. This does not diminish the respect of the panel for the general assessment policy in place, which is considered exemplary for other programmes alike.

Based on the quality of the theses and the interviews with alumni and the professional field, the panel concludes that graduates of the master's programme Biomedical Engineering master the intended learning outcomes and are sufficiently skilled to work in the field of biomedical technology, both in academic and professional settings. The programme convincingly manages to do what it intends to do, namely to produce graduates that can 'develop conceptual models from a technical perspective and work in close collaboration with physicians, researchers and other healthcare professionals, including on-site at the collaborating academic institutions'.

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

*Master's programme Biomedical Engineering*

| | |
|---|---|
| Standard 1: Intended learning outcomes | good |
| Standard 2: Teaching-learning environment | satisfactory |
| Standard 3: Student assessment | good |
| Standard 4: Achieved learning outcomes | good |
| | |
| General conclusion | good |

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

# DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK ASSESSMENTS

**Standard 1: Intended learning outcomes**
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

**Findings**

*Mission and goals*
The master's programme Biomedical Engineering (BME) at Delft University of Technology is an interfaculty programme jointly delivered by three faculties: the Faculty of Mechanical, Maritime and Materials Engineering (3mE), the Faculty of Applied Sciences and the Faculty of Electrical Engineering, Mathematics and Computer Science.

It is a multidisciplinary programme which aims to provide students with both an understanding of biology and medical theory as well as specialised technical training in the fields of physics and electrical, material and mechanical engineering. Students learn how to develop conceptual models from a technical perspective and work in close collaboration with physicians, researchers and other healthcare professionals, including on-site at the collaborating academic institutions. The acquired knowledge and skills are used in the development, design, and continuing refinement of devices such as joint replacement prostheses, microsensors, imaging and image processing, as well as advanced instruments for use in such domains as minimally invasive surgery and the diagnosis of movement disorders.

Starting in the study year 2018–2019, the BME programme changed from a structure based on six specializations to a more general structure composed of three tracks. The track Musculoskeletal Biomechanics is focused on understanding the biomechanics of the musculoskeletal system with the aim to improve the vitality of healthy people, enhance the performance of sports professionals and to treat the patients suffering from musculoskeletal disorders and diseases. Medical Devices & Bioelectronics provides an integrated platform to enable development of advanced medical devices including biomaterials, design models and fabrication processes for implantable devices, biosensors, medical instruments, external prostheses, orthoses, as well as diagnosis and disease monitoring systems. Medical Physics is aimed at the application of physical methods in health care, aiding in the standardization, calibration, and purchase of medical instruments, in close cooperation with medical and paramedical professionals. The goals of this change to three tracks are to harmonize the programme and to define more recognizable fields of application and cope with growing influx of students and to improve student awareness of employment options after study.

The panel is positive about the mission and goals of the programme. It shows a focus of the master's programme Biomedical Engineering on engineering in a clinical context, combining theory, design and technological implementation of biomedical technology, for instance in the realisation or testing of prototypes. Based on interviews with students, alumni and representatives of the professional (medical) field, the panel concludes that  this focus is widely recognized and shared. The panel is impressed to establish that the programme is tailored to yield competent researchers, as well as competent designers. The balance between those two aspects varies for each individual student depending on his or her specialization and thesis topic. The panel establishes this as a positive quality, giving students a choice on which aspect they focus. The management of the programme shows that it is certain and self-conscious on its role and positioning within the field.

The programme has good ties with the professional field, and uses these to align its goals with the expectation of potential employers of graduates. Participating groups and faculty members collaborate closely with the Medical Delta network, hospitals and companies in the region through collaborative research, guest lectures, internships and graduation projects. The Faculty of 3mE also has an Industrial Advisory Board, with professionals from Mechanical, Biomedical and Materials Engineering fields. This faculty-wide Industrial Advisory Board advises the faculty on policy discussion, curriculum changes, research reviews and the profile of 3mE graduates. Next to this, the programme management is currently working on setting up a dedicated advisory board for the master's programme. The panel welcomes the intention of the management to set up an Industrial Advisory Board specifically tailored to the master's programme Biomedical Engineering alongside the faculty wide Industrial Advisory Board, and would welcome an industrial advisory board with a sufficiently broad scope for the field of work of biomedical engineering to be covered.

*Intended learning outcomes*
The programme's goals are summarized in thirty-seven intended learning outcomes (ILOs), divided in seven broad competence areas, which are listed in Appendix 3. The panel studied them in terms of level, orientation and content. It concludes that the ILOs are clearly tied to the Dublin descriptors. This was demonstrated in an overview presented to the panel in which the programme's goals are shown to be tied with the 4TU Criteria for Academic Bachelor's and Master's Curricula (the so-called Meyers criteria), which cover the Dublin descriptors. As a result, the master's level and academic orientation are adequately visible in the ILOs. The ILOs are clearly described and constitute a solid link with the research done in the field of biomedical engineering. The panel is impressed with the level in which the intended learning outcomes tie in with the level and orientation of the programme; they are very well geared to the expectations of the professional field, the discipline, and international requirements.

The programme could consider a fine-tuning in the formulation of specific subgroups of the ILOs (ILOs 2D: Deal with the changeability of the research process, 3D: Deal with the changeability of the design process, 5F: Remain professionally competent); these seem to show some duplication, and an alternate formulation could contribute to better assessing these specific goals. The panel appreciates the work done by the programme to profoundly formulate the ILOs.

**Considerations**
The panel establishes that the intended learning outcomes of the programme are adequate in terms of level and orientation. They are profoundly formulated and geared towards the expectations of the professional field through frequent interactions with this field. The programme has a clear profile within the field of biomedical engineering, focusing on the implementation of technological solutions. The programme's goals and aims are well-suited to achieve this goal and aims to produce competent designers as well as researchers.

**Conclusion**
*Master's programme Biomedical Engineering:* the panel assesses Standard 1 as 'good'.

**Standard 2: Teaching-learning environment**
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

**Findings**

*Curriculum*
The curriculum consists of three tracks: Musculoskeletal Biomechanics, Medical Devices & Bioelectronics, and Medical Physics. The first year of the programme consists of 14 ECTS of obligatory courses for all three tracks, 24–25 ECTS of obligatory courses per track, 10-14 ECTS of track-pre-selected electives and 11-12 ECTS of free elective courses. An overview of the Biomedical Engineering curriculum 2018-2019 is presented in Appendix 4. The general goal of the courses offered is to provide students with a solid understanding of fundamentals of the relevant scientific topics, as well as the state-of-the-art aspects of Biomedical Engineering that will allow them to successfully address current and future challenges in this multidisciplinary field. All students get courses in experimental

design and statistics, anatomy and physiology, medical technology and ethics of healthcare technology. Additionally, students in the track Musculoskeletal Biomechanics follow courses focusing on tissue biomechanics and biomechatronics. In the track Medical Devices & Bioelectronics, students follow courses on topics such a biomaterials and 3D printing. Medical Physics students get subjects on for instance medical imaging systems, radiology and photon & proton therapy.

The second year of the programme is devoted to the graduation project. The goal of the second year is to allow students to work independently on complex problems, using the tools and methods provided with in the first year, and to develop new theory and design methods to solve complex biomedical engineering problems. In this respect, students must carry out the following activities: an internship (15 ECTS), attend student colloquia (1 ECTS), give a presentation at the Literature and Introduction Colloquium (2 ECTS), write a literature survey (10 ECTS) and perform a research project that results in a master thesis (32 ECTS).

The panel has studied the content of the programme and several courses, and concludes that it allows students to achieve the programme's intended learning outcomes. Students have the opportunity to develop their research and design skills in the courses Experimental Design, Statistics & the Human, and in Medical technology I & Healthcare Systems, and have the opportunity to work on the implementation of biomedical technologies in the internship, colloquia and the graduation project. The medical and technological domains are integrated within the courses by means of applications and examples.

As a result of the previous assessment of the master's programme Biomedical Engineering, the obligatory coarse Anatomy and Physiology was introduced for all tracks to ensure that students with an engineering background have sufficient knowledge of these subjects. The panel welcomes this change, and gathered from the interviews that this is shared by both students and teaching staff.

*Structure and coherence*

Starting in 2018-2019, the programme has undergone a number of structural changes in order to improve the coherence between specializations. Previously, the programme was structured around chairs of the participating three faculties. It was mainly structured through specialization-specific and elective courses. This resulted in variation in difficulty and study load between the six original specialisations as well as individual study programmes. Also, students and alumni indicated that the work load throughout the year was sometimes imbalanced, with periods of high and low work load during a year. This partly resulted from variation between the intended work load (ECs) and the amount of time students actually have to put for some courses.

The management of the programme sought to solve these issues by restructuring the initial chair-based six specialisations along the lines of the three interfaculty tracks mentioned above, and reduce the number of elective courses. The first year is structured into general compulsory courses, and track-specific compulsory and elective courses to better balance the workloads of individual students' programmes. The panel agrees with the programme management that the introduction of these tracks is expected to lead to a better structured programme, simplify the composition of individual student programmes. This will also aid in coping with the current strong rise in student numbers of students enrolling into the programme, as composing and approving of individual study programmes is a time-consuming effort. Teaching staff, students as well as the professional field are very positive about this restructuring of the programme. The panel is positive of the restructuring of the programme described above, and recommends the programme management to carefully monitor the equal spread of the amount of EC and workload per period in the new situation to see whether the desired result is achieved.

The programme has had an influx of students from very different bachelor's programmes, which means that they had very different background knowledge. To obtain a sufficient amount of connection between the knowledge and skills of students from different bachelor's programmes and the masters' programme Biomedical Engineering, students had to bridge the knowledge gap by taking additional electives while already enrolled in the programme. Recently, the programme introduced a structured bridging programme of 30/60 ECs to be taken before enrolment, with a content tailored to the specific needs for students enrolling into the Biomedical Engineering programme from different bachelor's programmes. This will ensure that students start the programme with sufficient skills and knowledge, freeing up time and elective space in the first year of the programme.

*Teaching staff*
The teaching staff, although coming from three different faculties, are very much involved in the programme. They all very much feel that they 'are biomedical engineers', a subject that 'is in essence interdisciplinary' and conduct innovative research along this line. Teachers feel part of a community, which ensures an active informal communication amongst teachers.

Teaching quality and motivation is considered to be important by the Faculty of 3mE and the management of the master's programme. For example, the selection process at the Faculty of 3mE requires all candidates for academic positions to give a trial lecture and present a teaching statement in addition to a research statement. Almost all teaching staff involved in the programme has obtained the University Teaching Qualification (UTQ). New staff members must complete the UTQ programme, while in recent years existing staff members have been tested by a professional education board and have performed peer reviews of their courses with their colleagues. The teaching staff themselves informally inform each other or ask for collegial advice with regard to practical matters that arise when teaching courses in the programme. Performance in education is evaluated and awarded during the annual evaluation of staff members (R&D cycle).

Teaching staff is encouraged to look for novel didactical methods and work forms. Most of all, teachers are stimulated by each other, but also by the management and the students, to innovate their ways of teaching. Teachers are free to shape their teaching of a course for themselves, where several teachers actively seek to shape their teaching along novel didactical lines, and others stick to more traditional didactical structures. Given the rising student numbers, the programme has acknowledged that novel didactical concepts like 'flipping the classroom' or 'blended learning' can also yield a more efficient way of working for the teaching staff. Teachers actively seeking for novel teaching modes get active support from the educational bureau. The teaching of the programme is supported by adequate facilities, such as a mock operating theatre, where students can practice development in a controlled clinical setting, and state of the art laboratory facilities. Also, the programme is able to use medical facilities from the Erasmus Medical Centre and Leiden University Medical Centre.

The large increase in Biomedical Engineering students has intensified the workload of the teachers within the programme. The programme management has realised this, and has a coherent plan to address this issue which was shared with the panel. The panel welcomes the plan to deal with the growing student numbers and is looking forward to its implementation and monitoring. Additionally, it could be beneficial to monitor the division of students along the three tracks of the programme, to see if the teaching capacity and expertise within a track keeps pace with the amount of students in the track.

*Feasibility of the programme*
Students generally take longer than two years to complete their studies. The panel acknowledges several causes for this. The previous lack of a bridging programme between the programme and the wide variety of previous bachelor's programmes the students originate from is one of them. The programme is in the process of addressing this, as described above. Talking to students, alumni and staff members, the panel observed other causes. Students experience a culture in which they are often pushed to put extra time in to get a better grade for their graduation project, even if this takes longer than required.

Also, internships in general take substantially longer than the amount of time set within the curriculum. Students feel encouraged to do their internship abroad, and about 80 percent of them does so. In the curriculum, 3 months are reserved for the internship, but companies in general (esp. international companies) require students to put in 6 months. This is facilitated and sometimes encouraged by the programme without increasing the number of associated credits. The panel advises the programme to safeguard the amount of time students put in the programme, and push back the amount of time that is put in beyond the curricular time reserved for these activities. It is advisable that the programme takes responsibility for this, and that it doesn't make students entirely responsible for this. This could be achieved by, for instance, taking into account the amount of time a student has put in when judging a graduation project, limiting the time spent on internships or by crediting students with the sufficient amount of ECs for a 6 month internship.

*Student support*
Before the start of the programme, students go on an introductory camp to familiarize them with shape and content of the programme, and to shape their personal programme before they actually start. This is welcomed by students and teachers, because students begin already knowledgeable and prepared at the very start of their studies. Students are free to follow their own interests and to expand their studies accordingly.

The panel observes that students are very much involved in shaping the programme. For instance, the programme has taken the initiative to form a student panel, that addresses the question how courses fit within the programme, and how they experience the integration in various disciplines.

In talking to students, staff, programme management and alumni, the panel is impressed by the – formal and informal – possibilities for student feedback. For instance, each course has a feedback loop for which students fill in a questionnaire, courses have groups of students assigned to monitor the course and give feedback to the teacher if necessary. The educational committee has student members, who give feedback to the programme management on courses and teachers when necessary. This feedback is bundled and reported to the programme committee very three months. More informally, individual students can give feedback to teachers, and every two weeks student representatives have a cup of coffee with the head of educational and student affairs, and the director of education, to talk about matters at hand. The panel, listening to students and alumni, gets the impression that teachers do listen to the feedback, but that the outcome of the feedback and the changes made because of the feedback could be made clearer. Students then also know that their feedback is useful because they can see what the outcome is.

**Considerations**
The panel assesses a clear, sufficient relationship of the programme with the ILOs. The academic orientation, as well as coupling with the professional field and the acquired skill set, meet the standard. The teaching staff is very well qualified, novel didactical concepts like 'flipping the classroom' are stimulated and supported by the programme. Feedback from students is made possible by a multitude of ways. Students are heard and are very much involved in the programme, and in shaping their own studies.

The panel is positive on the changes currently being implemented in the programme to improve its coherence and feasibility, mainly the restructuring in three tracks and the introduction of a bridging programme, although it still had to be proven in practice at the time of the site visit. It advises the programme management to monitor carefully how these measures address the fit of new students within the programme and the coherence and workload of the programme. It also advises to monitor the workload of the teachers involved in each track. To increase the feasibility of the programme, the panel also advises the programme to push back the amount of time that is put in beyond the curricular time reserved for the internship and the graduation project.

**Conclusion**
*Master's programme Biomedical Engineering:* the panel assesses Standard 2 as 'satisfactory'.

| **Standard 3: Student assessment** |
|---|
| The programme has an adequate system of student assessment in place. |

**Findings**

*Assessment policy*
By reading the self-evaluation of the programme, and speaking with the programme management, teachers of the programme and the Board of Examiners, the panel was able to get a clear and positive picture on the assessment policy and the factual implementation of this policy by teachers in the programme. The assessment policy of the BME programme is part of the assessment policy of the Faculty of 3mE. The Faculty of 3mE bases its assessment policy on the assumption that the staff is qualified and intrinsically motivated to provide high-quality assessment. The Faculty's full vision and policy on assessment is described in the document 'Toetsing bij 3mE'.

All examiners for the compulsory courses in the BME programme are employed by TU Delft, and hold (or are obtaining) the UTQ certificate. In the process of constructing tests, examiners must apply the 'four-eyes' principle, with another colleague being involved, in the interests of safeguarding the quality of assessment. This can vary from the provision of feedback to doing trial tests, discussing the answer model, and jointly determining the pass mark. Examiners must make a test matrix in advance as a blueprint for their exams to guarantee constructive alignment. A feedback procedure for exams was introduced to better monitor test quality. Once every three years, the educational advisor assesses and provides feedback on the exams for obligatory courses, focusing on test issues such as reliability, validity, construction and the safeguarding of the learning goals. At the end of every semester, the educational advisor writes an evaluation, with findings and recommendations to the Board of Examiners and the Director of Education.

As of 2017–2018, the Faculty of 3mE has decided to use two methods to determine pass marks: the Angoff and Hofstee. The Angoff method concerns estimating the difficulty of the question in relation to the performance of a minimally competent student. The Hofstee method corrects for unforeseen factors, such as the difficulty, quality and subjectivity of the exam. The Angoff and Hofstee methods form part of an analysis instrument that lecturers can subsequently use to analyse exams and exam questions. For written exams, students receive their grades within 15 working days after the exam date. Students have the right to obtain feedback on the exams that they have taken. Within 20 working days of the exam, each lecturer organizes an office hour for students, in which they can go through their exams and ask questions. Students increasingly receive digital scans of the exams they have taken.

The panel is firmly impressed by the quality of this assessment plan. In order to be able to adequately determine whether a student has attained the final qualifications, every form of assessment is tailored to the learning goals and teaching formats (constructive alignment). The panel considers that the actual frequent use of the Angoff and Hofstee methods to determine pass marks is exceptionally good. Rising student numbers might pressurise the ways of conducting assessment and the panel would like to encourage the programme to ensure that the quality of the assessment is retained with the use of open questions and a sufficient amount of variation.

*Board of Examiners (BoE)*
The assessment policy is set up and monitored by the Board of Examiners (BoE). The BoE is responsible for eight programmes within the Faculty of 3mE, one of which is the master's programme Biomedical Engineering. Its main focus is the quality of assessment of course units and projects, monitoring the exit level of individual students through rules and regulations, and the quality assurance of the thesis assessment. The BoE has set strict rules for the compilation of graduation committees, and checks if these rules are followed. It regularly monitors if the guidelines for assessment are followed, by reviewing reports of test evaluations, and by sample-wise review of graduation theses and the assessment documents of graduation projects. The BoE meets with the dean and board of education multiple times a year to spot possible issues concerning assessment. It

consists of a chair, a secretary, one member of each of the departments in the programme and an external member from another department of the faculty. Every three weeks the Board of Examiners meets to talk about assessment policy, to check examinations, and to treat individual cases. The BoE has a fraud and appeal committee and protocols in place for procedures to be followed when dealing with such cases.

The panel appreciates that this BoE has successfully designed and implemented a state of the art assessment plan. Adding to this, the panel has spoken with a BoE which proactively monitors if the assessment policy is followed and if the level of the master's theses is met.

*Internship assessment*
The panel has spoken to students and teachers about the internship that students conduct. The goal of the internship is mainly for students to acquire experience in a professional setting. At the moment, the internship is assessed by awarding a pass/fail by the director of education, after assessing a checklist and a report on the internship delivered by the company. The way that the internship is assessed could be aligned better with the overall policy of assessment within the programme. The panel recommends adding learning goals for each student and a transparent assessment rubric for each internship.

*Graduation assessment*
In the graduation phase, students must write a scientific report, present their findings at a public colloquium and defend their work before a graduation committee. This committee should consist of at least two scientific staff members and one postdoc or PhD candidate, one staff member should be from another section or preferably another department. The chair should be a full or associate professor who is authorized by the BoE to sign the master certificate. The supervisor is a member of the committee. Industrial partners can take part in the committee as guests. Since 2016–2017, when a candidate is eligible for the cum laude distinction, the committee should comprise one additional scientific staff member. As of 2017–2018, this member has to be employed in another department. The proposal of the graduation committee should be sent to the BoE for approval well in advance.

The panel is very positive about the graduation committee. Presenting and discussing with the committee will make for a weighted assessment. The Board of Examiners has set strict rules for the compilation of graduation committees, and firmly checks if these rules are met. Each master thesis is scored after presentation of the thesis by means of a grading rubric. The panel is positive about the use of the rubric. The panel would like to suggest that the programme would consider to fine-tune the wordings of some of the criteria in the rubric that deal with the score 'sufficient'. Also, for each criterion the panel suggests that some qualitative feedback would be in place, so the reason why a student has reached a certain goal is clearer.

**Considerations**
The Board of Examiners is operating actively and adequately to safeguard that the assessment remains of a high level, and is aware of potential pitfalls that might arise in implementing the assessment policy. The panel highly values the assessment plan and is impressed with the achieved level of implementation of this policy amongst the teachers of the master's programme. The assessment of the final theses is considered transparent and very adequate, following the structural use of a Master Thesis Grading Rubric. Beside the rubric, some qualitative feedback would be in place, to further clarify the given score. For the internships, the panel advises a structural use of learning goals and an associated rubric. This does not diminish the respect of the panel for the general assessment policy in place, which is considered exemplary for other programmes alike.

**Conclusion**
*Master's programme Biomedical Engineering:* the panel assesses Standard 3 as 'good'.

**Standard 4: Achieved learning outcomes**
The programme demonstrates that the intended learning outcomes are achieved.

**Findings**

To assess the achieved learning outcomes of the programmes, the panel studied a sample of 15 theses, and interviewed several alumni of the programme, as well as representatives of the professional field (companies and medical centres).

The panel considered the theses to be of good quality, both in content and structure. The topics are focused and show a nice combination of medical and technical content. The master's theses that the panel studied show a clear integration of clinical context and relation with the biomedical field and entail a fitting combination of theory, design and realisation and/or testing prototypes. Students show innovative skills and creativity, for instance the development of a new method or a new (thoroughly tested) technological implementation. Reporting is good in terms of content and presentation, and results are well evaluated with respect to the involved background literature.

In speaking with the panel, graduates indicated that the programme taught them an appropriate blend of research and design skills, as well as academic skills. They indicate that the acquired research skills are a good preparation for a scientific career. For a career outside academia, graduates indicate their acquired problem solving skills (i.e. cooperating with external parties and anticipating on a diverse set of practical problems) and knowledge of the medical standards or the ability to find out what they are as key selling points. The professional field confirmed this to the panel. The field recognises and values the medical knowledge and skills of the graduates, and their ability to quickly acquire knowledge of the clinical setting in, for instance, a hospital. For instance, graduates are comfortable to step into an operating theatre and design facilities for such a setting.

Graduates indicate that companies in a lot of the cases find them, instead of the other way around. They are in high demand and are employed as PhD researchers in the Netherlands or abroad, in biomedical companies and hospitals, and also for a large part in consultancy.

**Considerations**
Based on the quality of the theses and the interviews with alumni and the professional field, the panel concludes that graduates of the master's programme Biomedical Engineering master the intended learning outcomes and are sufficiently skilled to work in the field of biomedical technology, both in academic and professional settings. The programme convincingly manages to do what it intends to do, namely to produce graduates that can 'develop conceptual models from a technical perspective and work in close collaboration with physicians, researchers and other healthcare professionals, including on-site at the collaborating academic institutions'.

**Conclusion**
*Master's programme Biomedical Engineering:* the panel assesses Standard 4 as 'good'.

# GENERAL CONCLUSION

The panel assesses Standard 2 as 'sufficient' and Standards 1, 3 and 4 as 'good'.

According to the decision rules of NVAO's Framework for limited programme assessments, the panel assesses the master's programme Public Administration as 'good'.

**Conclusion**
The panel assesses the *master's programme Biomedical Engineering* as 'good'.

# APPENDICES

# APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

***A. Domain specific requirements for level and orientation of graduates***

Biomedical Engineering (BME) is an engineering discipline focused at the interface of engineering and life sciences. BME education should include basic general engineering requirements (as for example indicated by ABET) and a thorough understanding of life sciences.

BME programs must demonstrate that their students attain, according to the shared Dublin descriptors:

***Knowledge and understanding:***
- Knowledge of the basic disciplines mathematics, sciences, and engineering (mechanical, electrical, and chemical engineering and applied physics) to be applied in the field of Biomedical Engineering in a broader sense; i.e. including directly adjacent fields.
- Knowledge and understanding of concepts of physiology, (cell-) biology, anatomy, biochemistry, pharmacology and pathology as applicable in the field of Biomedical Engineering.

***Applying knowledge and understanding:***
- The capability to apply and integrate advanced mathematics, sciences, and engineering to model and solve complex biomedical problems (see also d).

***Making judgments:***
- An ability to conduct scientific research in areas of biomedical engineering and technology that are relevant to the advancement of knowledge and insight into fundamental and applied aspects of health and disease.
- An ability to make measurements on and interpret data from living systems, addressing problems associated with the interaction between living and non-living materials and systems.
- An ability to translate a clinical or health-relevant problem or question into an experiment, system, component, or process (design) to meet desired needs and, governed by scientific research or modeling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

***Communication:***
- A capability to bridge the gap between fundamental and applied research in biomedical engineering and medical (life) sciences by:
  1. Demonstrating an ability to communicate effectively in written and verbal form, and
  2. Collaboration in a multidisciplinary setting, which may include clinicians, other healthcare workers and industrialists alike.

- An awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of his/her research.

***Learning skills:***
- An ability to develop new concepts within the field of BME.
- An ability to study international scientific research.
- Recognition of the need for, and an ability to engage in life-long learning.

***B. Domain specific requirements of the BSc (Cycle 1) and MSc (Cycle 2) programs***

The Bachelor's program focuses on general knowledge, based on advanced textbooks and including some aspects informed by knowledge of the forefront of their BME specialization, basic skills and solving recognizable problems.

The Master's program focuses on deepening theoretical knowledge in one or more specific parts of Biomedical Engineering and provides ample experience in setting up, executing and reporting research and design. It leads to an attitude of scientific involvement.

***BSc students acquire***
***Knowledge and understanding in:***

- Basic beta disciplines: mathematics, sciences, and engineering (mechanical, electrical, and chemical engineering and applied physics) to be applied in the field of Biomedical Engineering in a broader sense; i.e. including directly adjacent fields.
- Life sciences: physiology, (cell-) biology, anatomy, biochemistry, pharmacology and pathology as applicable in the field of Biomedical Engineering.

***BSc students learn to***
***Apply knowledge and understanding:***

*a.* Of mathematics, sciences and engineering to model and solve simple biomedical problems.

***Make judgments:***

- Involving the making of measurements on and the interpretation of simple data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems at a basic level.

- Involving the ability to translate simple clinical or health-relevant problems or questions into an experiment, system, component, or process to meet desired needs and, governed by scientific research or modeling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

- By demonstrating an awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of his/her research.

***Communicate:***

- By bridging the gap between fundamental and applied research in biomedical engineering and medical (life) sciences by:
- Demonstrating an ability to communicate effectively in Dutch in written and verbal form, and
- Collaboration in a multidisciplinary setting.

***BSc students acquire***

***Learning skills:***

- As demonstrated in their recognition of the need for, and an ability to engage in lifelong learning at the BSc+ level with a high level of autonomy.

***MSc students acquire***

***Knowledge and understanding:***

- Of in depth biomedical engineering, in a coherent set of specialties, that builds on the basic knowledge acquired in the Bachelor's phase, and that provides a basis or opportunity for originality in developing or applying ideas in this specialization.

***MSc students learn to***

***Apply knowledge and understanding:***

- In order to apply and integrate advanced mathematics, sciences and engineering knowledge as well as specialized knowledge to model and solve complex biomedical problems in new and unfamiliar environments.

***Making judgments:***

- In an ability to conduct scientific research in areas of biomedical engineering and technology that are relevant to the advancement of knowledge and insight into fundamental and applied aspects of health and disease.
- An ability to make measurements on and interpret complex data from living systems, addressing the complex problems associated with the interaction between living and non-living materials and systems, and the ability to successfully recognize and address new problems in this field.
- An ability to translate a complex, not well-defined, clinical or health-relevant problem or question into an experiment, system, component, or process to meet desired needs and, governed by scientific research or modelling, to advise in issues like clinical research in biomedical engineering, diagnosis and therapy.

***Communicate:***

- With a capability to bridge the gap between complex fundamental and applied research in biomedical engineering and medical (life) sciences by
    1. Demonstrating the ability to communicate effectively in written and verbal form in Dutch and English, by underpinning knowledge and rationale (restricted scope) to specialist and non-specialist audiences alike, and
    2. Collaboration in a multidisciplinary setting, which may include clinicians, other healthcare workers and industrialists alike.

- An awareness of potential societal and ethical implications of scientific research in Biomedical Engineering and, in this context, an ability to critically evaluate the effects of the research carried out under his/her responsibility.

***Learning skills***

1. An ability to study international scientific research.
2. Recognition of the need for, and an ability to engage in life-long learning at MSc+ level in a manner that may be largely self-directed or autonomous.

***C. Description of derivation process of sections A and B***

The formulation of the Domain specific requirements have taking into account our mutual aims, requirements, and experiences from other sources. In the past, representatives of the programs participate in international discussions on BME education and accreditation (Europe: the BIOMEDEA project [project leaders: Joachim Nagel, Stuttgart, Dick Slaaf, Eindhoven, and Jan Wojcicki, Warsaw] under the auspices of EAMBES, the European Alliance of Biomedical Engineering and Science; USA: Whitaker BEES I (2000) and BEES II (2005) summit on BME education and accreditation in Lansdowne, Virginia.

The derivation process included the following steps:

- Comparison with standards derived by the academic BME community
    - Netherlands: compilation of the aims of the BME programs, which were based on international surveys (see below). In-line with basic requirements of engineering programs such as Mechanical Engineering, Applied Physics, etc.
    - Europe
    - European BME programs did not serve as reference, since no fully integrated Bachelor/Master's programs were available at the time.
    - EAMBES
        - IFMBE White paper on harmonization and accreditation of European BME programs,
        - BIOMEDEA conferences, papers and discussions
- USA
    - The IFMBE-White paper
    - Whitaker Foundation:

  - Information on website
  - First and second BEES summit
- and personal contacts from:
  - Duke University, Durham
  - Marquette University, Milwaukee
  - Northwestern, Evanston
  - University of Illinois, Chicago
  - Case Western Reserve University, Cleveland
  - Rensselaer Polytechnic institute, Troy
  - Massachusetts Institute of Technology, Boston
  - University of Pennsylvania, Philadelphia
  - Drexel University, Philadelphia
  - Johns Hopkins University, Baltimore
  - University of Utah, Salt Lake City

- Comparison with standards of independent bodies

- NL: BME degree program standards were not available. KIVI, the Dutch engineering alumni association has set up a BME branch, but standards for BME still have to be prepared.

- Europe
  - EAMBES-BIOMEDEA: The process of harmonization of accreditation is ongoing. We are actively participating.
  - EURACE: the European Accreditation of Engineers is active in preparing evaluation standards of engineering programs in Europe. The process is rather similar to that of QANU. However, they formulated no BME standards.
- USA
- ABET: Accreditation Board of Engineering and Technology. ABET has general engineering standards and specific standards for BME.

- Field of employment
  - NL: no representation yet. Each program has its own External Advisory Board or is setting it up. We used their input. The BME-branch of the Royal Institute of Engineers (KIVI/NIRIA) is active in the field of employment.

It is interesting to note that the BME student societies SvBMT Protagoras (TU/e), Idun (RUG) and Paradoks (UT) are actively seeking contacts with the field of employment.

- Europe: ESEM.
- USA: BMES, lead society for BME in ABET. BMES formulates the specific BMES standards for ABET.

# APPENDIX 2: INTENDED LEARNING OUTCOMES

**1. Competent in the scientific discipline Biomedical Engineering**

A graduate in Biomedical Engineering is able to:

1A. Apply a broad and profound knowledge of engineering sciences (mathematics and applied physics) to biomedical problems.
1B. Apply general and more advanced but specialized knowledge of anatomy and physiology to general and selected biomedical problems.
1C. Apply the knowledge of engineering sciences at an advanced level in at least one Biomedical Engineering specialization.
1D. Design, perform and evaluate experiments.
1E. Reflect on standard methods and their presuppositions and to questions these, propose adjustments, and to estimate their implications.
1F. Independently spot gaps in own knowledge and to independently revise and extend it through study.

**2. Competent in doing research**

A graduate in Biomedical Engineering is able to:

2A. Independently generate new scientific knowledge and new insights within the field of Biomedical Engineering.
2B. Assess research, including scientific literature, within Biomedical Engineering on its scientific value.
2C. Individually produce and execute a research plan and to choose the appropriate level of abstraction.
2D. Deal with the changeability of the research process.
2E. Draw upon other disciplines, especially those from the medical field, in own research.

**3. Competent in designing**

A graduate in Biomedical Engineering is able to:

3A. Systematically design complex biomedical systems.
3B. Generate innovative contributions to the discipline of Biomedical Engineering.
3C. Independently produce and execute a design plan, and to choose the appropriate level of abstraction.
3D. Deal with the changeability of the design process.
3E. Draw upon other disciplines, especially those from the medical field, in own design.
3F. Formulate new research questions on the basis of a design problem.

**4. A scientific approach**

A graduate in Biomedical Engineering is able to:

4A. Identify and take in developments in the Biomedical Engineering domain.
4B. Critically examine existing theories, models, or interpretations within Biomedical Engineering.
4C. Analyse problems and use modelling, simulation, design and integration towards solutions.
4D. Document adequately the results of research and design, and to publish these results to contribute to the development of knowledge in the Biomedical Engineering field and beyond.
4E. Reason logically within the field of Biomedical Engineering and beyond, to recognize modes of reasoning, and to recognize fallacies.

**5. Basic intellectual skills**

A graduate in Biomedical Engineering is able to:

5A. Analyse and solve technological problems in a systematic way.
5B. Identify and acquire lacking expertise.
5C. Critically reflect on own knowledge, skills and attitude.
5D. Plan and execute research in changing circumstances.
5E. Integrate new knowledge in an R&D project, considering ambiguity, incompleteness and limitations.
5F. Remain professionally competent.
5G. Take a standpoint with regard to a scientific argument within the research area.

**6. Competent in cooperating and communicating**

A graduate in Biomedical Engineering is able to:

6A. Work both independently and in multidisciplinary teams.
6B. Explain and defend outcomes from the research area to academia and industry, to specialists and a lay audience.
6C. Present and report in good English.

**7. Considering the temporal and social context**

A graduate in Biomedical Engineering is able to:

7A. Apply a broad knowledge of medical ethics and medical statistics in own work.
7B. Understand and potentially implement the regulatory procedures required for certification of medical devices relevant to one biomedical engineering specialization.
7C. Evaluate and assess the technological, ethical and societal impact of own work.
7D. Act responsibly with regard to sustainability, economy and social welfare.
7E. Interact effectively within clinical and pre-clinical settings with clinicians and medical researchers.

# APPENDIX 3: OVERVIEW OF THE CURRICULUM

*Master's programme Biomedical Engineering*

| Course name | Course code | Q | Teacher | ECTS | Assessment method |
|---|---|---|---|---|---|
| **Obligatory** | | | | | |
| Experimental Design, Statistics & the Human | BM41045 | 3 | J.C.F. de Winter<br>D. Dodou | 2 | Homework assignments |
| Anatomy & Physiology | BM41055 | 1&2 | J. Dankelman<br>F.C. Meeuwsen | 4 | Weekly tests<br>Written exam |
| Medical Technology I & Healthcare Systems | BM41065 | 1&2 | F.C.T. van der Helm<br>B. van Vliet<br>D.H. Plettenburg | 5 | Written digital exam<br>Essays |
| Ethics of Healthcare Technologies | WM1401TU | 4 | A.L. Robbins-Wijnsberghe | 3 | Written exam |
| **Obligatory for the Musculoskeletal Biomechanics track** | | | | | |
| Neuromechanics & Motor Control | BM41040 | 3&4 | W. Mugge<br>F.C.T. van der Helm<br>A.C. Schouten<br>H.E.J. Veeger | 5 | Written exam<br>Computer tests<br>Assignments |
| Computational Mechanics of Tissues & Cells | BM41090 | 3&4 | A.A. Zadpoor<br>H.H. Weinans | 6 | Written exam<br>Reports |
| Tissue Biomechanics of Bone, Cartilage & Tendon | ME41045 | 1 | H.H. Weinans | 3 | Written exam |
| System Identification & Parameter Estimation | ME41065 | 1&2 | A.C. Schouten<br>F.C.T. van der Helm<br>W. Mugge | 7 | Written exam<br>Assignments |
| Biomechatronics | ME41085 | 3&4 | D.H. Plettenburg<br>F. van der Helm | 4 | Assignments<br>Written exam |
| **Three additional courses from the following list are also obligatory for this track** | | | | | |
| Biomaterials | BM41035 | 2 | I. Apachitei<br>L. Fratila | 4 | Written exam |
| 3D Printing | BM41155 | 3 | A.A. Zadpoor<br>J. Zhou | 4 | Reports<br>Written exam |
| Special Topics in Sports Engineering | ME41035 | 4 | H.E.J. Veeger | 3 | Portfolio |
| Multibody Dynamics B | ME41055 | 3 | A.L. Schwab | 4 | Home work<br>Computer exam |
| The Human Controller | ME41070 | 4 | D.A. Abbink | 3 | Written exam |
| Biomedical Engineering Design | ME41075 | 2 | D.H. Plettenburg | 4 | Project |
| Man-machine Systems | ME41080 | 2&3 | J.C.F. de Winter | 4 | Written exam<br>Assignments |
| Control System Design (or the more extensive course SC42015 - 6EC) | SC42000 | 1 | A.J.J. van den Boom | 3 | Written exam |

| Course name | Course code | Q | Teacher | ECTS | Assessment method |
|---|---|---|---|---|---|
| **Obligatory for the Medical Devices and Bioelectronics track** | | | | | |
| Biomaterials | BM41035 | 2 | I. Apachitei<br>L. Fratila | 4 | Written exam |
| Applied Experimental Methods | BM41050 | 4 | J.J. van den Dobbelsteen | 4 | Assignments<br>Presentations<br>Written reports |
| Medical Instruments A: Clinical Challenges & Engineering Solutions | BM41095 | 1 | D. Dodou<br>J. Dankelman<br>J.J. van den Dobbelsteen | 3 | Written assignments<br>Presentations |
| 3D Printing | BM41155 | 3 | A.A. Zadpoor<br>J. Zhou | 4 | Reports<br>Written exam |
| Active Implantable Biomedical Microsystems | EE4555 | 4 | W.A. Serdijn<br>V. Giagka<br>V. Valante<br>C. Strydis | 5 | Assignments<br>Presentations |
| Themes in Biomedical Electronics | ET4127 | 3 | A. Bossche<br>P.J. French<br>W.A. Serdijn | 4 | Mini theses<br>Homework |
| **Three additional courses from the following list are also obligatory for this track** | | | | | |
| Regenerative Medicine | BM41075 | 4 | L. Fratila<br>A.A. Zadpoor | 4 | Written exam |
| Computational Mechanics of Tissues & Cells | BM41090 | 3&4 | A.A. Zadpoor<br>H.H. Weinans | 6 | Written exam<br>Reports |
| Medical Instruments B: Quality Assurance in Design | BM41100 | 3 | A.J. Loeve | 3 | Presentations<br>Assignment reports |
| Tissue Biomechanics of Bone, Cartilage & Tendon | ME41045 | 1 | H.H. Weinans | 3 | Written exam |
| System Identification & Parameter Estimation | ME41065 | 1&2 | A.C. Schouten<br>F.C.T. van der Helm<br>W. Mugge | 7 | Written exam<br>Assignments |
| Biomedical Engineering Design | ME41075 | 2 | D.H. Plettenburg | 4 | Project |
| System Engineering | EE4C02 | 3&4 | O. Yarovyi | 3 | Written exam<br>Assignments<br>Presentations |
| Structured Electronic Design | EE4C09 | 1 | C.J.M. Verhoeven | 5 | Written exam |
| Bioelectricity | ET4130 | 3 | V. Giagka | 3 | Written exam |
| Sensors and Actuators | ET4257 | 2 | P.J. French | 4 | Written exam/oral<br>Essays |

| Course name | Course code | Q | Teacher | ECTS | Assessment method |
|---|---|---|---|---|---|
| **Obligatory for the Medical Physics track** | | | | | |
| Advanced Digital Image Processing | AP3132 D | 3&4 | B. Rieger<br>F.M. Vos | 6 | Written exam<br>Assignments |
| Medical Imaging & Systems | AP3232 D | 3&4 | F.M. Vos<br>K.W.A. van Dongen<br>M.C. Goorden<br>W.J. Niessen | 6 | Assignments<br>Presentations<br>Written exam |
| Radiological Health Physics | AP3371TU D | 3 | M. Schouwenburg<br>M.J. van Bourgondien<br>K.R. Huitema<br>D.S. Dihalu | 6 | Written exam |
| Medical Physics of Photon & Proton Therapy | AP3582 | 3&4 | D. Lathouwers<br>M. Engelsman | 6 | Written/oral exam<br>Assignments |
| **Two additional courses from the following list are also obligatory for this track** | | | | | |
| Imaging Systems | AP3121 D | 1&2 | J. Kalkman<br>S. Stallinga | 6 | Midterm and final exam<br>MATLAB exercises |
| Acoustical Imaging | AP3531 | 3&4 | D.J. Verschuur | 6 | Oral exam<br>Assignments |
| Medical Visualization | IN4307 | 1 | A. Vilanova Bartoli | 5 | Assignments<br>Written/oral exam |
| Machine Learning | IN4320 | 3&4 | M. Loog<br>J.C. van Gemert<br>J. Kober<br>D.M.J. Tax | 6 | Reports<br>Assignments |

# APPENDIX 4: PROGRAMME OF THE SITE VISIT

**Thursday 18 October 2018**

| | |
|---|---|
| 08.30 – 09.00 | Arrival panel |
| 09.00 – 09.30 | Preparatory meeting panel |
| 09.30 – 10.15 | Programme Management + presentation |
| 10.15 – 10.30 | Break |
| 10.30 – 11.15 h | Lecturers |
| 11.15 – 11.30 | Break |
| 11.30 – 12.15 | Students |
| 12.15 – 12.45 | Panel deliberation, Lunch |
| 12.45-13.30 | Lab tour (cytocompatibility/biointerfaces lab) |
| 13.30 – 14.15 | Board of Examiners |
| 14.15 – 14.30 | Break |
| 14.30 – 15.15 | Alumni and Professional Field |
| 15.15 – 15.45 | Panel deliberation |
| 15.45 – 16.15 | Concluding conversation Programme Management |
| 16.15 –17.30 | Concluding panel session |
| 17.30 – 17.45 | Oral report preliminary assessment and feedback development dialogue |

# APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied the Self-evaluation MSc Biomedical Engineering (TU Delft October 2018), provided by the programme management, as well as 15 theses of the master's programme Biomechanical Engineering. Information on the selected theses is available from QANU upon request.

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

- TU Delft Vision on Education 2017
- Toetsing bij 3mE 2018
- Overzicht maatregelen ivm groeiende studentenaantallen BME 2018
- 3mE Vision on Education
- Benchmark with other BME programmes
- Criteria for Academic Bachelor's and Master's Curricula
- Jaarverslag opleidingscomissie Biomechanical Engineering 2016-2017
- Teaching and Examination Regulations MSc-BME
- Graduation Guide: Rules and guidelines for the MSc Programme and the taking of the MSc examination
- Results Employer Survey 2018
- BME film of lab facilities