MASTER’S PROGRAMME PHYSICS

FACULTY OF SCIENCE

AND ENGINEERING

UNIVERSITY OF GRONINGEN

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

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

Project number: Q0727

CONTENTS

This report was finalized on 1 October 2019

REPORT ON THE MASTER'S PROGRAMME PHYSICS OF UNIVERSITY OF GRONINGEN

This report takes the NVAO's Assessment Framework for the Higher Education Accreditation System of the Netherlands for limited programme assessments as a starting point (September 2018).

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Master's programme Physics

Name of the programme:	Physics
CROHO number:	60202
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Quantum Universe Advanced Materials Science, Business and Policy
Location:	Groningen
Mode of study:	full time
Language of instruction:	English
Submission deadline NVAO:	01/11/2019

The visit of the assessment panel Physics and Astronomy to the Faculty of Science and Engineering of University of Groningen took place on 13, 14 and 15 May 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

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

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 1 February 2019. The panel that assessed the master's programme Physics consisted of:

- Prof. dr. R. (Reinder) Coehoorn, full professor at the Eindhoven University of Technology, on the Physics and Application of Nanosystems. He is affiliated to the research group Molecular Materials and Nanosystems, in the Department of Applied Physics [chair];
- Prof. dr. M.J. (Margriet) Van Bael, professor at the Department of Physics and Astronomy of the Faculty of Science of the KU Leuven (Belgium);
- Prof. dr. G. (Garrelt) Mellema, professor at the Department of Astronomy of Stockholm University (Sweden);
- Prof. dr. S. (Sjoerd) Stallinga, professor and head of the Department Imaging Physics of Delft University of Technology;
- J. (Jeffrey) van der Gucht, BSc, master's student Physics and Astronomy at Radboud University [student member].

The panel was supported by dr. B.M. (Barbara) van Balen, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The master's programme Physics at the Faculty of Science and Engineering of University of Groningen was part of the cluster assessment Physics and Astronomy. Between April 2019 and June 2019 the panel assessed 17 programmes at 5 universities.

Panel members
The panel consisted of the following members:

- Prof. dr. R. (Reinder) Coehoorn, full professor at the Eindhoven University of Technology, on the Physics and Application of Nanosystems. He is affiliated to the research group Molecular Materials and Nanosystems, in the Department of Applied Physics [chair];
- Prof. dr. M.J. (Margriet) Van Bael, professor at the Department of Physics and Astronomy of the Faculty of Science of the KU Leuven (Belgium);
- Prof. dr. H. A.J. (Harro) Meijer, professor of Isotope Physics, chairman of the Centrum voor Isotopen Onderzoek (CIO) and director of the Energy and Sustainability Research Institute Groningen at University of Groningen;
- Prof. dr. G. (Garrelt) Mellema, professor at the Department of Astronomy of Stockholm University (Sweden);
- Prof. dr. S. (Sjoerd) Stallinga, professor and head of the Department Imaging Physics of Delft University of Technology;
- Prof. dr. G. (Geert) Vanpaemel, professor for History of Science and Science Communication at KU Leuven Belgium);
- J. (Jeffrey) van der Gucht BSc, master's student Physics and Astronomy at Radboud University [student member];
- B. N. R. (Bram) Lap BSc, master's student Astronomy at University of Groningen [student member];
- L. (Laura) Scheffer BSc, master's student Physics at Utrecht University [student member].

For each site visit, assessment panel members were selected based on their expertise, availability and independence.

The QANU project manager for the cluster assessment was Peter Hildering MSc. He acted as secretary in the site visit of Leiden University and Utrecht University. In order to assure the consistency of assessment within the cluster, the project manager was present at the panel discussion leading to the preliminary findings at all site visits and reviewed all draft reports. Dr. Barbara van Balen acted as secretary in the site visits of University of Groningen and the University of Amsterdam/Vrije Universiteit Amsterdam, and drs. Mariëtte Huisjes was secretary at Radboud University. The project manager and the secretaries regularly discussed the assessment process and outcomes.

Preparation
On March 15 2019, the panel chair was briefed by the project manager on the tasks and working method of the assessment panel and more specifically its role, as well as use of the assessment framework.

A preparatory panel meeting was organised on May 12 2019. During this meeting, the panel members received instruction on the tasks and working method and the use of the assessment framework. The panel also discussed their working method and the domain specific framework.

A schedule for the site visit was composed. Prior to the site visit, representative partners for the various interviews were selected. See Appendix 4 for the final schedule.

Before the site visit, the programmes wrote self-evaluation reports of the programmes and sent these to the project manager. He checked these on quality and completeness, and sent them to the panel members. The panel members studied the self-evaluation reports and formulated initial questions and remarks, as well as positive aspects of the programmes.

The panel also studied a selection of theses. The panel studied the work and the assessment forms of 10 students, based on a provided list of graduates between 2017-2018. For this selection, the panel used the opportunity to select a lower number of theses as described in the NVAO framework when there is significant overlap between the assessed programmes in a single site visit. In the case of the master's programme Physics, this overlap consists of a shared Board of Examiners with the bachelor's programme Physics and the bachelor's and master's programme of Applied Physics, as well as alignment of assessment procedures with the Astronomy Board of Examiners and an overlap in teaching staff between all six programmes. A variety of topics and tracks and a diversity of examiners were included in the selection. The project manager and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

At the moment of the site visit, no recent theses for students in the SBP track were available to the panel, as no Physics students participated in this faculty-wide track in the past years. For the realized learning outcomes for this track, the panel refers to the reports of other panels that considered this track at the Faculty of Science and Engineering, for instance Chemistry and Mathematics.

Site visit
The site visit to University of Groningen took place on 13, 14 and 15 May 2019.

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

During the site visit, the panel studied additional materials about the programmes and exams, as well as minutes of the Programme Committee and the Board of Examiners. 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 and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

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.

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

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

Meets the standard
The programme meets the generic quality standard.

Partially meets the standard
The programme meets the generic quality standard to a significant extent, but improvements are required in order to fully meet the standard.

Does not meet the standard
The programme does not meet the generic quality standard.

The panel used the following definitions for the assessment of the programme as a whole:

Positive
The programme meets all the standards.

Conditionally positive
The programme meets standard 1 and partially meets a maximum of two standards, with the imposition of conditions being recommended by the panel.

Negative
In the following situations:
- The programme fails to meet one or more standards;
- The programme partially meets standard 1;
- The programme partially meets one or two standards, without the imposition of conditions being recommended by the panel;
- The programme partially meets three or more standards.

SUMMARY JUDGEMENT

Standard 1
The master's degree programme Physics aims to produce physicists who are highly knowledgeable and skilled in fundamental physics as well as in the fields of the quantum universe and advanced materials at the interface with adjacent disciplines. It is the programme's vision that physics as a discipline is aimed at the fundamental understanding of nature, based on a quantitative observation of natural phenomena. The programme translated this vision into intended learning outcomes (ILOs) within the framework of the Dublin Descriptors and the domain-specific reference frame. The panel established that the ILOs are formulated in line with the mission and sufficiently indicate what could be expected from students at a master's level. They reflect the content, level and orientation of the master's programme and match the professional field.

Standard 2
Students can choose among three tracks in the master's programme: Advanced Materials, Quantum Universe, and Science, Business and Policy. All tracks are interdisciplinary. Common to the tracks are four compulsory 'Physics core' courses, in total 20 EC: Computational Physics, Mathematical Methods of Physics, Statistical Mechanics and Advanced Quantum Mechanics. In addition, there are four compulsory track-specific core courses for each research-oriented track (20 EC). The students also take 20 EC of track-specific electives. They apply the knowledge and understanding gained to train research skills during their Master Research Project lasting a year (60 EC) in a physics research group. The students call this Master Research Project the highlight of their studies.

The master's programme has a solid curriculum that offers students ample opportunity to specialise and deepen their knowledge and skills. The students are thoroughly trained in research. There is a good alignment between the ILOs and the curriculum. Students are given information about a career outside the academic world, and sufficient attention is paid to the development of non-technical skills. The teaching forms used in the master's programme are in line with the level and content of the curriculum.

The quality of the teaching staff is good. The panel noticed a strong improvement in the percentage of staff that is UTQ qualified. The university has an adequate policy and good intensive training programmes for enhancing the didactic quality of the teaching.

Standard 3
The programme director drafts an assessment plan annually at the programme level. In addition, a Course Unit Assessment Overview (CUAO) is available for each course. The programme uses different modes of assessment, such as written exams, assignments, oral exams, presentations, reports and research projects. The preferred assessment method gradually shifts towards ones more suited to assessing higher levels of knowledge and skills, reaching the level of independent creation during the research project.

The panel finds the assessment system and policy adequately developed and implemented. The courses use a variety of assessment methods, which are aligned with the learning outcomes and the curriculum. The procedures are transparent for teachers and students.

The panel is positive about the way the Board of Examiners is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable. It particularly values the Course Unit Assessment Overviews (CUAOs) for all courses.

Standard 4
The panel verified the alignment between the programme's intended learning outcomes and the courses and exams in the curriculum. It concluded that this alignment ensures that graduates have achieved the intended learning outcomes. It studied a selection of ten master's theses and their

assessments. The theses demonstrated that the minimum level required for a master's programme in physics had been reached and exceeded in many cases.

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

Master's programme Physics

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

The chair, Prof. Reinder Coehoorn, and the secretary, Dr. Barbara van Balen, 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.

Date: 1 October 2019

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

The master's degree programme Physics is provided by the Faculty of Science and Engineering of the University of Groningen. This Faculty also offers the bachelor's degree programmes Physics, Applied Physics and Astronomy and the master's programmes Applied Physics and Astronomy, which are also being assessed in this cluster assessment. This report concerns the assessment of the master's degree programme Physics; the assessments of the other master's and bachelor's degree programmes are described in separate reports.

The Faculty of Science and Engineering (FSE) is a large faculty, its programmes in research and education range from nanomaterials and bio-machinery to astronomy and also include mathematics, pharmacy, neurosciences, computer science and biology. Research at FSE is carried out in a number of institutes. Research institutes relevant for Physics are: Zernike Institute for Advanced Materials (ZIAM), Van Swinderen Institute for Particle Physics and Gravity (VSI), Environmental Sustainability Research Institute Groningen (ESRIG), KVI-Center for Advanced Radiation Technology (KVI-CART), Kapteyn Astronomical Institute (Kapteyn).

Within the FSE, the master's as well as the PhD programmes are organised within the Graduate School of Science (GSSE). The master's programmes are managed by the director of the GSSE together with the programme directors of the respective programmes. The management of the daily affairs of the master's degree programmes Physics, Applied Physics and Astronomy is in the hands of the programme director, programme coordinator and academic advisor. The master's programmes Physics, Applied Physics and Astronomy are taught in English in an international environment.

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
The master's degree programme Physics aims to produce physicists who are highly knowledgeable and skilled in fundamental physics as well as in the fields of the quantum universe and/or advanced materials at the interface with adjacent disciplines. The self-evaluation report states that physics as a discipline is aimed at fundamentally understanding nature, based on a quantitative observation of natural phenomena. This involves experimental measurements, data processing and analysis, mathematical and computational modelling, and the development of a rigorously tested theoretical framework with predictive power. The programme reflects this vision by offering compulsory education in core topics in physics and providing a choice of tracks that specialise in an area of physics that reaches out towards adjacent disciplines: Advanced Materials, Quantum Universe, and Science Business and Policy. The first two tracks have a research-oriented character, the last track prepares the student for a professional career in management and policy and is offered on a faculty-wide level.

The programme translated this vision into intended learning outcomes (ILOs) within the framework of the Dublin Descriptors (see Appendix 2) and the domain-specific reference frame (Appendix 1). This framework is used by all Physics and Astronomy programmes in the Netherlands. It was developed in a joint process at the European level (Tuning Physics) to align the Physics and Astronomy programmes at the international level.

The panel established that the ILOs are formulated in line with the mission and sufficiently indicate what could be expected from students at a master's level. They reflect the content, level and orientation of the master's programme and match the professional field. The distinction between the ILOs of the bachelor's and the master's programme is clear.

Since the last programme assessment, several improvements have been implemented on various issues, including curriculum changes. One of these improvements concerned the establishment of an external advisory panel. This panel provides the programme management with feedback about the connection of the degree programme with developments in the field. Next to this advisory panel several mechanisms are in place to regularly update the intended learning outcomes and to ensure that the intended learning outcomes keep pace with changes in society and the scientific discipline. The master's programme director keeps an overall eye on the programme to make sure that the various aspects of the curriculum remain balanced. The lecturers are involved in research at an internationally competitive level and therefore aware of the latest developments in their field and incorporate these, where appropriate, into the courses they teach. And furthermore, regular staff meetings are dedicated to teaching. The discussions in these meetings sometimes lead to a curriculum committee being instated about a certain topic. The panel appreciates the improvements and the mechanisms to ensure the regular evaluation and updating of the ILOs. It encourages the programme to continue in this line.

Considerations
The panel concluded that the intended learning outcomes of the master's degree programme Physics meet the Dutch qualification framework and the international standards. They sufficiently indicate the academic master's level.

The panel appreciates the strong research-oriented tracks offered in the master's programme as well as the interdisciplinary profile enabling students to combine the physics core with courses on adjacent subjects. It appreciates the improvements that the programme has made in the last period and the mechanisms to ensure the regular evaluation and updating of the learning outcomes. It encourages the programme to continue in this line.

Conclusion
Master's programme Physics: the panel assesses Standard 1 as 'meets the standard'.

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
Students can choose among three tracks in the master's programme. The panel finds it positive that all three tracks are interdisciplinary. The Advanced Materials track is a combination of Physics and Chemistry; the Quantum Universe track is a combination of Physics and Astronomy; and Science, Business and Policy is a combination of the original science discipline (physics in this case) and business management and policy. Common to the tracks of the master's programme are four compulsory 'Physics core' courses, in total 20 EC: Computational Physics, Mathematical Methods of Physics, Statistical Mechanics and Advanced Quantum Mechanics. There are four compulsory track-specific core courses for each research-oriented track (20 EC), denoted as QU (Quantum Universe) core and AM (Advanced Materials) core. These courses are taken together with students from Astronomy and Chemistry, respectively. The students also take 20 EC of QU-electives or AM-electives, which are physics courses on the topic of the track. Finally, they apply the knowledge and understanding gained to train research skills during their Master Research Project lasting a year (60 EC) in a physics research group. An overview of the master's curriculum is presented in appendix 3.

Irrespective of the track chosen, the student is supported in developing his/her academic skills through the Academic Skills module belonging to the Master Research Project, which focuses on searching the literature, scientific writing and presentation. Three other common elements are the Scientific Integrity module, the General Physics colloquium and the Career perspective module. Students are offered the possibility to perform part or all of their Master Research Project abroad. As with the regular Master Research Project done at the University of Groningen, students are provided with two supervisors from the Groningen Physics teaching staff, who also serve as examiners.

The students reported that they are satisfied with the content and level of the compulsory physics core and tracks courses. They find it interesting to hear experts discuss their own fields and research subjects and value the interdisciplinary approach. They appreciate the full year of research in the second year, as this gives them the opportunity to learn skills they can use in their professional career and to develop experience with long-term research projects. The master research project is seen as the highlight in the programme. The students have some recommendations for improvement: they would like to see more challenging computer skills being trained and used in the core physics courses and they would like to see statistics offered as a core physics module. The panel recommends considering these additions and, if deemed feasible, adding them to the curriculum. Overall, it considers the curriculum to be solid and is of the opinion that the programme offers students ample opportunity to specialise and deepen their knowledge and skills. It found the curriculum to be well developed, managed and implemented, and there is a good alignment between it and the intended learning outcomes.

Career prospects are elucidated by the study associations or the faculty-wide 'Beta Business days'. The students appreciated the information provided and the opportunity to meet representatives from companies in the field.

Teaching forms
From the earliest stage of the programme, education and research have been closely interwoven. Master students are expected to already have a fair degree of autonomy in acquiring new knowledge, skills and competences. This is reflected in the teaching methods. Oral lectures are therefore supplemented by modes of instruction that require active student participation through tutorials, assignments, presentations, practical classes and reports. There is training in research and academic skills as well as scientific integrity included in the programme. Especially in the Master Research Project, the students learn advanced research skills and acquire increasing autonomy as well as the capability to communicate research results to others. The small scale of the master's programme ensures active participation of the students in the courses. Small classes make it easy for lecturers to engage in two-way communication with the students and allow for discussions and presentations for all students.

Feasibility
The academic year is divided into two semesters, each divided into two periods of eight instruction weeks followed by two exam weeks. In every period three course components of 5 EC are taught. The nominal workload for students is 40 hours per week. There is a large percentage of dropouts each year. The programme management reports that investigation of these cases revealed that the cause is often the result of personal circumstances. The panel, however, thinks that is important to closely monitor these dropouts. It is of the opinion that students who have finished the bachelor's programme successfully should be able to graduate from the master's programme. The students stated in the self-evaluation report that the programme is feasible in the nominal duration. They described that more time is often needed to finish the Master Research Project. Relatively recently, a planning form has been provided in which deadlines are given for critical parts of the project and intermediate meetings. The students think that this form can help, and the panel agrees with them.

The panel deduces from this discussion that the curriculum is feasible, as there are no obvious obstacles in the programme itself. It advises closely monitoring the students and identifying the reasons for dropping out in order to be able to take measures to keep these students on track.

Staff
The tenured staff members contributing to the programme all have a PhD degree and are actively involved in research in one of the above-mentioned research institutes. Some 75% of the active teaching staff has acquired a University Teaching Qualification (UTQ), and 40% has an international

background. The panel established that the master's programme is taught by experts strongly connected to research institutes and that a high proportion of the tenured staff has sufficient didactical training.

The students are positive about the teachers; they reported that the teachers are accessible and very willing to help and to answer questions. They are also very positive about the added value of the academic advisor; she knows how to get things done and helps students with their planning.

The master's degree programme is taught in English in an international environment. This is necessary in the panel's view to achieve the level that is required for a master's degree in physics. An international academic environment community adds to the quality of the programme and prepares the students for their future career. The level of English proficiency of the teachers is sufficient. The panel finds the quality of the teaching staff to be good.

Considerations

The curriculum of the master's programme Physics enables the students to achieve the intended learning outcomes. According to the panel, the master's programme offers a solid curriculum that provides students with ample opportunities to specialise and deepen their knowledge and skills. The students are thoroughly trained in research. The panel found the curriculum to be well developed, managed and implemented, and there is a good alignment between it and the intended learning outcomes. It appreciated that students are given information about a career outside the academic world and have the opportunity to meet representatives of companies. It noticed that sufficient attention is paid to the development of non-technical skills and appreciated that the programme contains a course on scientific integrity as part of the master's thesis project. The teaching forms used in the master's programme are in line with the level and content of the curriculum.

Despite the relatively high dropout rate in the master's programme, the panel concluded that the programme is feasible. It is possible to graduate in two years, but the majority of students take longer. The panel advises closely monitoring the reasons for students to drop out.

The quality of the teaching staff is good, and students are positive about the quality and dedication of their teachers. The panel noticed a strong improvement in the percentage of staff who are UTQ qualified. The university has an adequate UTQ policy and good intensive training programmes to enhance the didactic quality of the teaching.

Conclusion

Master's programme Physics: the panel assesses Standard 2 as 'meets the standard'.

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

Findings

Assessment policy

An assessment plan is drafted annually by the programme director and approved by the Faculty Board. It consists of a list of examiners, modes of assessment of all course units, a list of individual Research Project supervisors, and a matrix clarifying the relationship between the learning outcomes of the course units and the final learning outcomes of the degree programme. In addition to this assessment plan at the programme level, a Course Unit Assessment Overview (CUAO) is available for each course. This overview is a systematic description of the links between the learning outcomes, modes of instruction and modes of assessment and grading, and the position of the course in the curriculum. These overviews are updated annually. A summary of the CUAO is made available to the students. The panel studied several CUAOs during the site visit. It is very positive about these overviews.

The programme uses different modes of assessment, such as written exams, assignments, oral exams, presentations, and practical work. The type of assessment chosen depends on the specific learning goals and aims to guarantee variation in the assessment forms per block.

As a rule, exams and assignments of course units are always drafted or checked by two lecturers (peer review). The Master Research Project is assessed using a standard assessment form based on four categories: scientific quality of research, management of research, colloquium/final presentation; report/thesis. At least two examiners are involved: the supervisor and a second examiner from a different research group, who is not directly involved in the research project under consideration. The panel reviewed the assessment form used for the research project and discussed its use as well as the procedure followed by the examiners with the teachers and the Board of Examiners during the site visit. It noticed that there is no grading rubric included on the form and that some of the completed forms lacked substantiation for the grades. It recommends formalising motivation of that grading on paper. The panel finds the assessment system and policy adequately developed and implemented.

Board of Examiners
Since the last programme assessment, several actions have been taken to strengthen the role and task performance of the Board of Examiners (BoE). The BoE is responsible for ensuring the quality of examinations and final assessments. The BoE for the bachelor's and master's degree programmes Physics and Applied Physics consists of four members, chosen from the teaching staff, and one external member. The BoE checks whether the Assessment Plan is appropriate for the intended learning outcomes of the programme, whether the suggested examiners are qualified for their role, whether there is sufficient variety in the modes of assessment, and whether they are appropriate for the specific learning outcomes.

To check the assessment of the master research projects, the BoE checks all theses with grades <7 or >8.5, as well as a few randomly selected theses each year. In the assessment period the BoE generally agreed with the grades awarded by the supervisors. One aspect of improvement identified by the BoE was that the supervisors could elaborate more on the justification of grades on the assessment form. This aspect was also noted by the panel, as described above.

The CUAO is an important instrument for the BoE to check the quality of the assessments of the course units. To ensure the quality of examinations, the BoE checks the assessments of about eight course units annually. The panel is positive about the way the BoE is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and the thesis assessment are transparent, valid and reliable.

Considerations
The panel finds the assessment system and policy adequately developed and implemented. The courses use a variety of assessment methods, which are aligned with the learning outcomes and the curriculum. The procedures are transparent for teachers and students.

The panel is positive about the way the Board of Examiners is performing its tasks. Its role has obviously been extended and improved in the assessment period. The panel concluded that the examinations, tests and thesis assessment are transparent, valid and reliable.

The panel particularly values the Course Unit Assessment Overviews (CUAOs) for all courses.

Conclusion
Master's programme Physics: the panel assesses Standard 3 as 'meets the standard'.

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

Findings
The BoE checks whether the content and depth of the exams reflect the requirements of the master's degree programme Physics as outlined in the ILOs. It uses the master's degree programme assessment plan for this check. This plan was also included in the self-evaluation report. According to the panel, the plan indicates that the master's programme Physics guarantees that students are educated regarding knowledge, skills, and attitude as specified in the programme's ILOs, and it concluded that the curriculum ensures that graduates have achieved the ILOs.

The panel studied a selection of ten master theses and their assessments. The theses showed that the minimum level required for a master's programme in Physics had been exceeded. The theses demonstrated that the graduates are clearly capable of carrying out research aimed at the understanding of physical phenomena and their description in scientific terms. They also indicated that the graduates can analyse a new, complex physical problem and use modelling skills to develop a structured and well-planned research approach. The panel noted that the graduates are capable of obtaining relevant information and drawing conclusions on the basis of limited or incomplete information, and are able to realise and formulate the limitations of such conclusions.

The self-evaluation report presented the results from a survey among alumni, indicating that 85% of the graduates got an job within four months after graduation, with the majority working in academia. The alumni rate the programme highly, which was confirmed during the site visit in the interview the panel conducted with a selection of alumni. The panel concluded that the graduates are well prepared for continuing in a PhD trajectory or a job in industry.

Considerations
The panel concludes that graduates of the master's programme Physics have achieved the intended learning outcomes. The minimum level had been reached and often exceeded. It found the level of the master's theses to be good and generally agrees with the grading of the theses. It would have graded some theses a bit higher and others a bit lower. The graduates are well prepared for continuing in a PhD trajectory or a job in industry.

Conclusion
Master's programme Physics: the panel assesses Standard 4 as 'meets the standard'.

GENERAL CONCLUSION

The panel judged that the master's programme in Physics offered by the University of Groningen meets all standards of the NVAO assessment framework for a limited programme assessment. It therefore recommends accreditation of the programme.

Conclusion
The panel assesses the *master's programme Physics* as 'positive.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Introduction

The goal of a university programme is to prepare students for an independent practice of the profession of the relevant discipline, and to give them the ability to apply the knowledge and skills they have acquired. Dutch university programmes in the domain of (applied) physics and astronomy are required to reach a level which allows the graduate to be competitive in the international research or in the job market, in particular with respect to countries which have a high profile in these areas. The domain specific reference frame is meant to be a gauge for reaching this goal.

The framework is based on that used in the Teaching Programme Assessment (Onderwijsvisitatie) of 2013. This in its turn was derived from the qualifications as formulated in the document 'Reference points for the design and delivery of degree programmes in physics', which was a product of the so-called Tuning Project63[1] and, to a lesser extent, the document 'A European Specification for Physics Master Studies' of the European Physical Society (2009). The 2013 framework has been modified and updated in three ways: (1) the programme descriptors are now divided over the usual five Dublin indicators, instead of over the original three categories: cognitive competences, practical skills, and generic competences, (2) several competences have been rephrased, (3) the competence 'Estimation skills' has been added.

The descriptors for the programmes have been formulated in terms of competences acquired by the graduating student, which leads to specific requirements for the curriculum. Programmes with the same name at different (Dutch) universities will in general not be identical. Different specialisations in the research staff or focus on particular subjects leads to differences in the eligible part of the programmes, and there is a structural difference between (the goals of) general universities and universities of technology. As a consequence, there are different ways to comply with the requirements of the reference frame. Essential is that the local choices for, and focus of the programme fit the internationally accepted standards.

Programme descriptors

Similarly to the Bachelor's degree programmes, the descriptors for the Master's degree programmes are divided over the five Dublin descriptors, where the highest or most relevant descriptor is used for this division. The number in the second column is the 'Rating of importance' at the Master's level mentioned in the Tuning Physics document. The competence 'Estimation skills' and the related competence 'Problem solving skills' are combined (ratings 2 and 9). The three colors indicate the type of competence: light color = core curriculum, medium color = familiarity with physics research, dark color = general skills.
The basic difference with respect to the descriptors for the Bachelor's programmes is the different emphasis. Where a Bachelor's programme aims at including some aspects of the forefront of knowledge, a Master's programme aims at providing a basis (or opportunity) for originality.

[1] In May 2018 a new version of the Tuning document was published, as output of the CALOHEE project (https://www.calohee.eu/). In this document, a different structure of competences is proposed (nine 'disciplines', each divided into 'knowledge', 'skills' and 'wider competences'). The compilers of the present framework have decided to follow the simpler, yet elegant structure of the Tuning 2008 document. Where relevant, aspects of the Tuning (2018) have been incorporated.

(A) Knowledge and understanding

	Rating of importance	Specific competence	Description. On completion of the degree course, the student should
A1	5	Knowledge and understanding of physics	have a good understanding of the important physical theories (logical and mathematical structure, experimental support, physical phenomena described).
A2	14	Understanding of the physics culture	be familiar with the most important areas of physics and with the common approaches, which span many areas in physics.
A3	8	Frontier research (MSc only)	have a good knowledge of the state of the art in (at least) one of the presently active topics in physics research.

(B) Applying knowledge and understanding

		Specific competence	Description. On completion of the degree course, the student should
B1	2, 9	Problem solving skills, Estimation skills	be able to frame, analyse and break down a problem in phases defining a suitable algorithmic procedure; be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems.

B2	1	Modelling skills	be able to identify the essentials of a process/situation and to set up a working model of the same; be able to perform the required approximations; *i.e.* critically think about how to construct physical models.
B3	7	Mathematical skills	be able to understand and master the use of the most commonly used mathematical and numerical methods.
B4	10	Experimental skills	have become familiar with most important experimental methods and be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data; and to be able to scientifically report the findings.
B5		Computer skills	be able to use appropriate software, programming language, computational tools and methods in physical and mathematical investigations.
B6	6	Familiarity with basic and applied research	acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, *e.g.* engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

(C) Judgement

C1	13	Human / professional skills	be able to develop a personal sense of responsibility; be able to gain professional flexibility through the wide spectrum of scientific techniques offered in the curriculum; be able to organize the personal learning process, evaluate personal work, consult experts for information (*e.g.* about career opportunities) and support when

			appropriate; have had the opportunity to take courses that prepare for teaching physics at secondary school, as well as the opportunity to gain in-depth interdisciplinary skills.
C2	18	Absolute standards	have become familiar with highly regarded research in the field, thus developing an awareness of the highest standards.
C3	17	Ethical awareness (relevant for physics)	be able to understand the socially related problems related to the profession, and to comprehend the ethical characteristics of research and of the professional activity in physics and its responsibility to society; be able to conduct processes of decision making and inspect the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.
C4	12	Management skills (MSc only)	be able to work with a high degree of autonomy, even accepting responsibility in (project) planning, and in the managing of structures.

(D) Communication

D1	11	Communication skills	be able to listen carefully and to present difficult ideas and complex information in a clear and concise manner to a professional as well as to lay audiences; be able to work in a multidisciplinary or in an interdisciplinary team.
D2	16	Language skills	be able to read, speak, and write in technical English.

(E) Learning

E1	3	Literature search	be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
E2	4	Learning ability	be able to enter new fields through independent study; have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy (lifelong learning).
E3	15	Updating skills (MSc only)	enjoy the facility to remain informed of new developments and methods, and be able to provide professional advice on their possible impact or range of applications.

APPENDIX 2: INTENDED LEARNING OUTCOMES

1. Knowledge and understanding
The master graduate in Physics
1.1. understands the advanced concepts of physics, including the necessary mathematics and computer science;
1.2. is familiar with the advanced quantitative character of physics and with the relevant research methods;
1.3. [Advanced Materials track] has a thorough understanding of the current state of the art in materials science, more specifically of the structure, functional properties and characterisation of advanced materials;
1.4. [Quantum Universe track] has a thorough understanding of the main fields and presently active topics in theoretical physics, more specifically in the fields of general relativity, statistical mechanics, quantum mechanics, particle physics and radiation processes;
1.5. [Science, Business and Policy track] has operational knowledge of, and insight into, the present functioning of companies and administrations, as well as the relevant legislation, in relation to physics oriented working areas.

2. Application of knowledge and understanding
The master graduate in Physics
2.1. is capable of carrying out research, aimed at the understanding of physical phenomena and their description in scientific terms;
2.2. is capable of analysing a (new) complex physical problem, and to use modelling skills to develop a structured and well-planned research approach;
2.3. is capable of applying his/her specific knowledge and mathematical, experimental, and computer skills to solve physical problems in his/her own and related fields;
2.4. is capable of collaborating in a (multi-disciplinary) team.

3. Judgement
The master graduate in Physics
3.1. is capable of obtaining relevant information using modern information channels, and to interpret this information critically;
3.2. is capable of managing and judging his/her and others' actions within a highly scientific and professional context, taking societal and ethical aspects into account;
3.3. is able to draw conclusions on the basis of limited or incomplete information, and is able to realize and formulate the limitations of such conclusions.

4. Communication skills
The master graduate in Physics
4.1. is capable of communicating clearly in English, both verbally and in writing, on his/her subject and relevant applications, at a level which is understandable to experts and non-experts, and by using modern communication tools.

5. Learning skills
The master graduate in Physics
5.1. is capable of addressing issues on new developments (using e.g. literature research) inside as well as outside his/her main subject area, therefore and thereby gaining new, updated knowledge and skills.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Quantum Universe (QU) track in the MSc Physics

Year 1

	Ia	Ib	IIa	IIb
Physics core (20 ECTS)	Computational Physics	Mathematical Methods of Physics	Statistical Mechanics	Advanced Quantum Mechanics
QU core (20 ECTS)	General Relativity	Electrodynamics of Radiation Processes	Particle Physics Phenomenology	Student Seminar QU
QU electives (20 ECTS)	Cosmic Structure Formation/ Laser Cooling and Trapping/ Lie Groups in Physics	Fundamental Constants/ Nuclear Astrophysics/ Quantum Field Theory	Star and Planet Formation/ Geometry & Differential Equations/ Statistical Methods in Physics/ Gravitational Waves	Big Experiments/ Elementary Particles/ Introduction to Plasma Physics/ Formation & Evolution of Galaxies

Year 2

	Ia	Ib	IIa	IIb
Master Project (60 ECTS)	_____________ Master Research Project _____________			

Curriculum of the Quantum Universe (QU) track in the MSc Physics, consisting of 40 ECTS of compulsory core modules (20 ECTS Physics core and 20 ECTS QU core), 20 ECTS of QU electives and a 60 ECTS Master Research Project (including the modules Academic Skills, Scientific Integrity, Career Perspective (from 2019/2020) and Physics Colloquium).

Advanced Materials (AM) track in the MSc Physics

Year 1

	Ia	Ib	IIa	IIb
Physics core (20 ECTS)	Computational Physics	Mathematical Methods of Physics	Statistical Mechanics	Advanced Quantum Mechanics
AM core (20 ECTS)	Cross-disciplinary Materials Science	Functional Properties* Structure at Macro, Meso & Nano Scale*	Characterization of Materials* Supramolecular chemistry*	
AM electives (20 ECTS)	Atomic and Molecular Interactions/ Surfaces and Interfaces	Statistical Signal Processing	Mechanical Properties/ Non-linear Optics/ Physics of Lasers/ Statistical Methods in Physics/ Theoretical Condensed Matter Physics	Many-particle systems/ Mesoscopic Physics/ Modern Laser Microscopy/ Polymer Physics/ Ultrafast Time-resolved Spectroscopy

Year 2

	Ia	Ib	IIa	IIb
Master Project (60 ECTS)	Master Research Project			

Curriculum of the Advanced Materials (AM) track in the MSc Physics, consisting of 40 ECTS of compulsory core modules (20 ECTS Physics core and 20 ECTS AM core), 20 ECTS of AM electives and a 60 ECTS Master Research Project (including modules Academic Skills, Career Perspective (from 2019/2020), Scientific Integrity and Physics Colloquium). *Students choose 3 out of these 4 courses.

Science, Business and Policy (SBP) track in the MSc Physics

Year 1/ Physics

	Ia	Ib	IIa	IIb
Physics core (20 ECTS)	Computational Physics	Mathematical Methods of Physics	Statistical Mechanics	Advanced Quantum Mechanics
Electives in Science (10 ECTS)	To be chosen out of courses in the MSc Physics, tracks AM or QU, or the MSc Applied Physics.			
Master Project (30 ECTS)	________________ Master Research Project ________________			

Year 2/ Science, Business and Policy

	Ia	Ib	IIa	IIb
SBP core (60 ECTS)	Introduction Science and Business (10 ECTS) Introduction Science and Policy (10 ECTS)	_____Internship Business and Policy (40 ECTS)_____		

Curriculum of the Science, Business and Policy (SBP) track in the MSc Physics, consisting of 80 ECTS of compulsory core modules (20 ECTS Physics core and 60 ECTS SBP core, divided into 20 ECTS of courses and a 40 ECTS internship), 10 ECTS of electives in Science (chosen from the Physics Master tracks QU (Table 1) and AM (Table 2) and from the MSc Applied Physics) and a 30 ECTS Master Research Project (including the modules Academic Skills, Career Perspective (from 2019/2020), Scientific Integrity and General Physics Colloquium).

APPENDIX 4: PROGRAMME OF THE SITE VISIT

12 mei

17.00 – 19.00	Internal panel meeting

Ma 13 mei

09.00 – 09.15	Arrival and welcome
09.15 – 09.45	Internal panel meeting
09.45 – 10.45	Management bachelor + master Physics + Applied Physics
10.45 – 11.00	Break
11.00 – 11.45	Bachelor and master students Physics
11.45 – 12.00	Break
12.00 – 12.45	Teaching staff Physics
12.45 – 13.30	Lunch + internal panel meeting
13.30 – 14.15	Show cases, poster presentations by students
14.15 – 14.30	Break
14.30 – 15.15	Bachelor and master students Applied Physics
15.15 – 15.30	Break
15.30 - 16.15	Teaching staff Applied Physics
16.15 – 16.30	Break
16.30 – 17.15	Board of Examiners Physics and Applied Physics
17.15 – 17.30	Break
17.30 – 18.15	Alumni + External Advisory Panel (combined)
18.15 – 18.45	Visit to the observatory

Di 14 mei

09.00 – 09.45	Internal panel meeting overleg
09.45 – 10.30	Management bachelor + master Astronomy
10.30 – 10.45	Break
10.45 – 11.30	Bachelor and master students Astronomy
11.30 – 11.45	Break
11.45 – 12.30	Teaching staff Astronomy
12.30 – 13.00	Lunch
13.00 – 13.30	Consultation hour
13.30 – 14.15	Tour of the facilities and poster presentation students
14.15 – 14.30	Break
14.30 – 15.15	Board of Examiners Astronomy
15.15 – 16.00	Internal panel meeting preparation meeting with formal management
16.00 – 17.00	Formeel management (combined)

Wo 15 mei

09.00 – 12.00	Concluding panel meeting, formulating judgements
12.00 – 12.15	Preliminary feedback
12.15 – 12.30	Break
12.30 – 13.30	Development Dialogue (combined) – incl. lunch

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 10 theses of the master's programme Physics. 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):

- Course Unit Assessment Overviews of a sample of courses
- Study Handbooks
- Internship reports, including the assessment forms
- Exemplary journal articles used in the courses
- Year reports of the Boards of Examiners and the Programme Committees
- Quality Assurance Manuals