- UNOFFICIAL VERSION -

Departmental Examination Regulations (FPO-M)
for the

Master's Degree in

Quantum Science (QS)

at the
University of Siegen

Dated 21 June 2023

(Master’s Degree Program in Quantum Science (QS))

These regulations consolidate the current valid regulations as established in:

- The *Fachprüfungsordnung (FPO-M) für das Fach Quantum Science (QS) im Masterstudium an der Universität Siegen* dated 21 June 2023 (*Amtliche Mitteilung* 36/2023).
- Note: This unofficial version is only provided for informational purposes. Only the German-language regulations as formally published in an *Amtliche Mitteilung* from the University of Siegen are legally binding.

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Article 1
Scope

(1) These Departmental Examination Regulations, together with the General Examination Regulations (RPO-M) for the master's degree at the University of Siegen from 28 February 2019 (*Amtliche Mitteilung* 5/2019), as amended, govern studies in the subject of Quantum Science (QS).

(2) Article 2 contains regulations for studies in the subject of Quantum Science as a single subject degree program.

Article 2
Regulations for the Single Subject Degree in Quantum Science

§ 1
Degree Program Model

(1) The master's degree program in Quantum Science is available as a single subject degree program.

(2) The master's degree program in Quantum Science is offered in two variants:

1. For students with prior knowledge of quantum mechanics ("Q");
2. For students with no prior knowledge of quantum mechanics ("NQ").

The selection of a concentration is made at the time of enrollment in the degree program.

§ 2
Objectives for the Degree Program

The consecutive master's degree program in quantum science is an academic, research-oriented degree program. The course of studies explores core topics in quantum physics and conveys the skills required to develop interdisciplinary methods and processes to solve problems in the field of quantum science and then apply those in a professional manner. The specialist content and the graduate-level instructional offerings related to key qualifications have been specifically organized to prepare students to work scientifically in research and industry. Another goal is the conveying of key soft skill qualifications such as communication and teamwork, as well as presentation and the ability to function as a moderator. The international orientation of the degree program will help students build up a network within Germany and abroad.

§ 3
Master's Degree

After successful completion of the course of study, the university awards the academic degree of "Master of Science" (M.Sc.).

§ 4
Special Admission Requirements

(1) Supplemental to § 4 RPO-M, one precondition for admission to the master's degree program in quantum science is proof of a first-cycle university degree in a bachelor's degree program in physics, mathematics, computer science, or electrical engineering from the European Higher Education Area. Admission is also to be granted to candidates holding a first-cycle higher education degree of a comparable specialization, insofar as the examination board observes no essential differences between the degrees and degree programs denoted in Sentence 1.

(2) Prerequisite for admission to the degree program variant "with prior knowledge of quantum mechanics ("Q")" is a previously earned bachelor's degree with at least 15 credit points in the area of "theoretical and experimental quantum physics." Students who earned a bachelor's degree with fewer than 15 credit points in the field of "theoretical and experimental quantum physics" are only eligible for admission to the degree program variant "without prior knowledge of quantum mechanics (NQ)."

(3) The degree denoted in Paragraph 1 must be a qualified degree in the meaning of § 4 para. 2 RPO-M. This is the case if it can be proven that the degree was acquired with a grade of at least 2.7.

(4) One addition prerequisite for admission to the master's degree in quantum science is proof of English mastery at the B2 level or higher according to the Common European Framework of Reference for Languages (CEFR) or at least an 88 on the TOEFL iBT (Internet based TOEFL) or an IELTS of 6.5.

(5) Enrollment will be barred to a candidate who has finally failed an examination in a degree program of notably similar content to the desired degree program and where the examination regulations define the examination in question as essential for the desired degree program

§ 5
Time Abroad and Internships

(1) Neither time abroad nor internships are mandatory.

(2) Voluntary stays abroad are recommended only after the 2nd specialist semester [*Fachsemester*]. To promote better acceptability of modules completed abroad, a learning agreement regulating the acceptability of work completed abroad should be concluded prior to the stay abroad.

§ 6
Examination Board

(1) To handle the responsibilities denoted in Section 8 RPO-M and in this article, Faculty IV — School of Science and Technology will form an examination board for the single subject master's degree program in quantum science. The examination board can delegate tasks to the Office of Examinations.

(2) The examination board is comprised of

1. four members of the teaching faculty,
2. one member of the academic staff, and
3. two members of the student body.

The members of the Examination Board for Quantum Science must be members of Faculty IV — School of Science and Technology.

(3) The term of office for members of the teaching faculty and academic staff totals three years. The term of office for members of the student body totals one year. Re-election is permissible.

(4) For members pursuant to Paragraph 2, deputies shall be elected in the event that appointed members are unable to attend, with a term of office based on Paragraph 3:

1. Two deputies for members of the teaching faculty,
2. one deputy for the member of the academic staff, and
3. one deputy for the student members.

§ 7
Examiners, Observers

(1) Authority to conduct an examination will be oriented toward § 9 RPO-M.

(2) The examiner for the module “Preparation Project“ (4QSMA06) serves as the lead assessor for the master’s thesis.

(3) Observers for oral examinations will be determined by the examiner and must be qualified in the field. This qualification is to be documented through a completed *Diplom* or master's degree in an engineering or natural sciences degree program from Faculty IV — School of Science and Technology or a comparable degree.

§ 8
Credit Point Requirements and Structure of the Degree Program

(1) Successful completion of the master’s degree in quantum science requires 120 credit points (CP).

(2) The standard term of study totals 4 semesters. The course of studies can only be undertaken full time. The course of studies for the “Q” degree program variant can begin in either the winter or summer semester. The “NQ” degree program variant may only be started in the winter semester.

(3) The course of studies in the “Q” degree program variant encompasses compulsory courses within three modules (21 CP, cf. Paragraph 9) and the mandatory “Preparation Project” (18 CP; 4QSMA06) as a preparatory phase for the master's thesis, as well as the “Core Elective Courses (Q)” (51 CP, cf. Paragraph 5 in conjunction with Annex 4) and the master’s thesis (30 CP, 4QSMA07).

(4) The course of studies in the “NQ” degree program variant encompasses compulsory courses within five modules (36 CP, cf. Paragraph 9) and the mandatory “Preparation Project” (18 CP; 4QSMA06) as a preparatory phase for the master's thesis, as well as the “Core Elective Courses (NQ)” (36 CP, cf. Paragraph 6 in conjunction with Annex 4) and the master’s thesis (30 CP, 4QSMA07).

(5) The “Q” degree program variant includes six to nine modules (51 CP) from the compulsory courses (Q), covering the fields of “Quantum Topics,” “Methods and Applications,” and “Miscellaneous” topics related to the degree program in quantum science. At least two modules encompassing at least 12 CP in the area of “Quantum Topics” and two modules encompassing at least 12 CP in the area of “Methods and Applications” must be completed. Modules assigned to multiple areas can only be counted toward one area within the meaning of Sentence 2.

(6) The “NQ” degree program variant includes four to six modules (36 CP) from the Core Electives Courses (NQ), covering the fields of “Quantum Topics,” “Methods and Applications,” and “Miscellaneous” topics related to the degree program in quantum science.

(7) Modules should be selected from the core electives courses as per Paragraphs 5 and 6 so as to achieve the precise number of prescribed credit points. If the selection of modules produces more than the prescribed number of credit points, then the student must apply for recognition of the modules from the core elective courses prior to the completion of their studies, with indication of how many credit points from the individual modules should be recognized, so that the sum of the respective core electives courses reaches the prescribed number of credit points. The module grades are calculated together with the recognized CP totals into the final grade.

(8) An elective module can only be taken once within the framework of the core elective courses. The selection of the elective module is performed through registration for the corresponding

examination credit. A module that was already accepted for a previous bachelor's degree program cannot be selected as an elective module.

(9) Module Overview:

No.	Module	CW[1]	EX[2]	CP[3]	C / CE[4] "Q"	C / CE[4] "NQ"	Link to module description
Compulsory area							
4QSMA01	Concepts of Quantum Science	1-2	0	6	C	C	Annex 7
4QSMA02	Seminar: Quantum Science	1	1	6	C	C	Annex 7
4QSMA03	Mini Research Project	1	1	9	C	C	Annex 7
4QSMA04	Quantum Phenomena	1-2	1	6	-	C	Annex 7
4QSMA05	Introduction to Quantum Theory	1-2	1	9	-	C	Annex 7
4QSMA06	Preparation Project	1	0	18	C	C	Annex 7
Core Elective Courses (Q)							
	6-9 modules from the core electives courses as per Para. 5	1-9	3-9	51	CE	-	Annex 4
Core Elective Courses (NQ)							
	4-6 modules from the core electives courses as per Para. 6	0-2		36	-	CE	Annex 4
Master's Thesis							
4QSMA07	Master's Thesis	0	1	30	C	C	Annex 7

[1] CW = Coursework **I** [2] EX = Examination **I** [3] CP = Credit Points **I**

[4] C/CE = Compulsory/Core Elective for degree program variant "Q" or "NQ".

The recommended specialist semester (*Fachsemester*) is determined from the degree program curriculum (Annex 1).

(9) Potential instructional formats are: lecture, exercise, seminar, lab, or preparation project. The concrete instructional format must be listed in the module description.

(10) Instruction is fundamentally conducted in English. Within the core electives courses, however, individual courses can potentially be taught in other languages. Insofar as the language of instruction is not clearly defined, the instructor will announce the language of instruction at the start of the respective course.

§ 9
Coursework and Examination Credits

(1) Supplemental to § 10 para. 1 and § 11 para. 6 RPO-M, the following formats are stipulated for coursework and examination credits:

1. Coursework:

   a) Regular/active participation in the seminar or exercise, through contribution to the discussion, presentations, or submission of exercise problems;

   b) Written Test (90-120 minutes);

   c) Oral Test (20-40 minutes);

   d) Project internship (experimental, theoretical, or numerical work in a research group);

   e) Participation in a research school, incl. 3-5 page written report;

   f) Preparation for the master's thesis with final expert discussion:

      Orientation in the topic and preparation for the master's thesis, including an expert discussion and review with lead assessor of master's thesis (approx. 30 minutes);

g) Participation in an industrial internship incl. written report (3- 10 page);

h) Exercise tasks (at least 50% correctly completed);

i) Exercise and project problems (1-12 problems, time limit of approx. 10-135 hours);

The prescribed practice and project tasks must be completed as homework, with the solutions submitted to the instructor in a timely manner. The provision of the solution can come through submission in written or electronic form and/or through a brief oral presentation (5-15 minutes). The precise form of submission and/or presentation will be determined by the instructor and announced at the beginning of the course. The number, type, and scope of tasks are reflected in the respective module description;

j) Lab:

All experiments for the lab must be completed. Beyond this, written lab reports (5-15 pages per experiment) are to be created and submitted to the instructor. The results are presented as part of a colloquium or final discussion (15-30 minutes per examination);

k) Seminar presentation (15-20 minutes) with written assignment (5-15 pages):

The following related academic achievements are to be completed:

aa) Conduction of a presentation on an assigned topic in German or English.

bb) Preparation of a written assignment on the content of the presentation in German or English. The written assignment is to be submitted to the instructor prior to the presentation.

cc) Participation in the other seminar presentations and active participation in the discussion about the presentation topics.

The topics of the presentations and dates for the presentations, as well as the deadlines and form of written assignment, will be announced by the instructor no later than two weeks after the start of the respective course. The length of the presentation and scope of the written assignment will be specified in the respective module description;

j) Programming task with presentation (15-30 minutes).

2. Examinations:

a) Written examination (90-180 minutes);

b) Oral test (20-45 minutes);

c) Seminar presentation (60-90 minutes);

d) Written report (approx. 15 pages);

e) Experiment reports (3-6 reports).

(2) In derogation of § 11 para. 4 RPO-M, it is possible to withdraw from examination dates that were not organized and announced via the campus management system or the examination board, but rather individually with the examiner, up to 7 days before the start of the examination or the agreed-upon submission deadline. Notice of withdrawal is to be submitted to the examination board.

(3) Students can apply to perform additional coursework or examination credits (supplementary credits). Supplementary credits can be coursework or examination credits from unselected modules for this degree program or another bachelor's degree program at the University of Siegen. Supplemental credits are not counted into the final grade; no credit points are applied toward this degree program for supplemental credits. Successfully completed supplemental

credits are always included on the Transcript of Records; by request, the supplemental credits can be removed from the Transcript of Records. Application must be made to the Office of Examinations at latest prior to the announcement of the final examination credit of this degree program. Once a module has been completed and listed as a supplemental credit, it can no longer be booked and denoted as a course from the core electives courses.

§ 10
Repetition of Examinations

(1) Admission to the Master's Thesis will be oriented toward § 12 RPO-M.

(2) For modules imported from other departmental examination regulations, derogations of Paragraph 1 are permissible.

(3) After the first and second failed examination attempt, the candidate can perform an oral supplementary examination for the modules 4QSMA02 to 4QSMA05 with the respective examiner. The supplementary exam must be completed within four months after announcement of the grade and does not represent an independent repetition of the examination. The supplementary examination cannot be repeated. The supplementary examination does not apply to the cases enumerated in § 18 para. 1, 5, 5a, 6, and 8 or 18a RPO-M.

(4) If a written examination from a module from FPO-B PHYS or FPO-M PHYS is graded as "Failing" (5.0) and would represent a result of a 'finally failed' for the module, the candidate can apply for an oral supplementary examination in the modules within a deadline of 14 days after announcement of the failing marks. Sentence 1 does not apply for module 4PHYMA09. The supplementary examination is conducted by two examiners, of which one should be the examiner from the written examination. Based on the supplementary examination, the grades of "sufficient" (4.0) or "failing" (5.0) can be set as the results for the examination credit. The supplementary examination does not apply to the cases enumerated in § 18 para. 1, 5, 5a, 6, and 8 or 18a RPO-M.

(5) For examination credits in the form of a written examination, the last possible examination attempt should generally be conducted as an oral examination; by request of the student, a repeated attempt in written form is possible, insofar as this form is offered for the examination. For modules imported from other departmental examination regulations, derogations of Sentence 1 are permissible.

§ 10a
Diagnostic Test/"Free Shot"

(1) Up to two examination credits from the modules 4QSMA02 to 4QSMA05 and the modules from FPO-B INF, FPO-M INF, FPO-B ET, and FPO-M ET that have not yet been repeated as per § 12 para. 5 RPO-M and which were taken in the semester foreseen in the curriculum can, by request of the student to the chairperson of the examination board, be assessed on a one-time basis as a diagnostic test and then be repeated.

(2) If the repeated examination achieves a better grade than the prior attempt, then the prior attempt will be considered not attempted and the examination attempt will be replaced by the repetition. If the repeated examination produces an equal or worse grade, then the grade from the previous attempt will count.

(3) An oral examination is to be repeated within six months, all other examinations at the next-possible date, otherwise the right to a diagnostic test/"free shot" will expire. A second "free shot"

is not allowed for the same examination credit. The student must request an oral examination appointment from the examiner.

(4) An examination credit that was declared failed due to inappropriate behavior, and in particular an attempt to cheat, cannot be assessed as a diagnostic test/"free shot."

§ 11
Master's Thesis

(1) The master's thesis (master's thesis and colloquium) is worth 30 credit points (CP) towards the master's degree.

(2) Application for admission to the Master's Thesis is to be submitted in writing to the Examination Board. Admission to the Master's Thesis will be oriented toward § 13 RPO-M. The following additional requirements must also be fulfilled:

a) The candidate from degree program variant "Q" has at least 48 CP and completed the following modules:

Module Number	Module Name
4QSMA01	Concepts of Quantum Science
4QSMA06	Preparation Project

b) The candidate from degree program variant "NQ" has at least 33 CP and completed the following modules:

Module Number	Module Name
4QSMA01	Concepts of Quantum Science
4QSMA04	Quantum Phenomena
4QSMA05	Introduction to Quantum Theory
4QSMA06	Preparation Project

(3) The master's thesis must be prepared in the English or German language. The candidate has the right to propose the topic of the thesis as well as one assessor. Following a consultation with the proposed lead assessor, the chairperson of the examination board will select a lead assessor and second assessor as well as the topic of the master's thesis. The topic of the master's thesis will be distributed by the chair of the examination board. Pursuant to § 11 para. 15 RPO-M, the grade for the master's thesis will be announced no later than 10 weeks after the submission deadline.

(4) Twenty-six (26) weeks' working time is allotted for the master's thesis. The length of the master's thesis should not exceed 120 pages. The topic of the master's thesis may only be changed once, within eight weeks after the start of the working time.

(5) If the master's thesis is to be conducted at an institution outside the university, then permission from the chairperson of the examination board must be acquired. The external institution must confirm in writing their acceptance of the regulations for the master's thesis.

(6) Three copies of the master's thesis are to be submitted as a printed, bound book. It should be submitted to the examination board via the office of examinations. The printed copy serves as the basis for evaluation by the first assessor and the second assessor. In addition, an electronic copy of the master's thesis compatible with the search function is to be submitted together with all annexes (such as programming code, models, technical drawings, or circuitry diagrams).

(7) Any portions of the work that quote other works, either verbatim or in their intellectual content, must be denoted as such, including a citation of the source. The candidate will add a written pledge to the thesis confirming that they completed it on their own, did not use any sources or aids other than those cited, and that all quotations are attributed as such.

(8) The master's thesis will be defended in a colloquium (approx. 30 min. presentation open to members of the university community together with a 10 to 20-minute follow-on discussion). The colloquium can only be held after submission of the master's thesis. The grade for the colloquium represents 25% of the grade for the master's thesis.

§ 12
Grades, Calculation of Grades

(1) Grades will be calculated based on § 21 RPO-M.

(2) The grade for each group of compulsory or core elective courses is calculated from the arithmetic mean of the individual grades as weighted based on the credit points for the respective module.

(3) The final grade for the degree program variant "NQ" is calculated 30% from the grade for the compulsory courses, 30% from the grade for the core elective courses, and 40% from the grade for the master's thesis.

(4) The final grade for the degree program variant "Q" is calculated 17.5% from the grade for the compulsory courses, 42.5% from the grade for the core elective courses, and 40% from the grade for the master's thesis.

§ 13
Application and Transitional Rules

These Departmental Examination Regulations apply for all students who have enrolled for the first time in this master's degree program at the University of Siegen starting with winter semester 2022/2023.

Article 3
Regulations for the Degree Component as Part of Combination Degree Program (Non-Teacher Education)

Not applicable.

Article 4
Regulations for the Degree Component as Part of Teacher Education

Not applicable.

Article 5
Cross-Departmental Export Modules

Not applicable.

Article 6
Entry into Effect and Publication

(…)

This set of regulations governs the entry into effect of the original department examination regulations.

Annexes

Curricula

Annex 1: Curricula by degree model for single major degree programs in Article 2

1. Degree Program Variant Q, starting in winter semester

Semester	CP	Module	CW	EX	CP
1st	**30**	4QSMA01 Concepts of Quantum Science	1-2	0	6
		Core Electives Courses	0-2	1-4	24
2nd	**30**	4QSMA03 Mini Research Project	1	1	9
		4QSMA02 Seminar: Quantum Science	1	1	6
		Core Electives Courses	0-2	1-3	15
3rd	**30**	4QSMA06 Preparation Project	1	0	18
		Core Electives Courses	0-2	1-2	12
4th	**30**	4QSMA07 Master's Thesis	0	1	30

2. Degree Program Variant Q, starting in summer semester

Semester	CP	Module	CW	EX	CP
1st	**30**	4QSMA03 Mini Research Project	1	1	9
		4QSMA02 Seminar: Quantum Science	1	1	6
		Core Electives Courses	0-2	1-3	15
2nd	**30**	4QSMA01 Concepts of Quantum Science	1-2	0	6
		Core Electives Courses	0-2	1-4	24
3rd	**30**	4QSMA06 Preparation Project	1	0	18
		Core Electives Courses	0-2	1-2	12
4th	**30**	4QSMA07 Master's Thesis	0	1	30

3. Degree Program Variant NQ, starting in winter semester

Semester	CP	Module	CW	EX	CP
1st	**30**	4QSMA01 Concepts of Quantum Science	1-2	0	6
		4QSMA04 Quantum Phenomena	1-2	1	6
		4QSMA05 Introduction to Quantum Theory	1-2	1	9
		Core Electives Courses	0-2	1-2	9
2nd	**30**	4QSMA03 Mini Research Project	1	1	9
		4QSMA02 Seminar: Quantum Science	1	1	6
		Core Electives Courses	0-2	1-3	15
3rd	**30**	4QSMA06 Preparation Project	1	0	18
		Core Electives Courses	0-2	1-2	12
4th	**30**	4QSMA07 Master's Thesis	0	1	30

Annex 2: Curricula by degree program for combination degree programs (non-teacher training)
Combination Degree Program as per Article 3

Not applicable.

Annex 3: Curricula by degree model in teacher education in Article 4

Not applicable.

Core Elective Modules

Annex 4: List of core elective modules pursuant to Article 2 § 8 para. 5 and 6

No.	Module	CW	EX	CP	Link to module description
Field "Quantum Topics"					
4QSMA08	Research School: Quantum Science	1	0	3	Annex 7
4PHYMA02	Experimental Quantum Optics	1	1	9	FPO-M Physics
4PHYMA04	Quantum Information Theory	1	1	9	FPO-M Physics
4PHYMA05	Fundamentals of Quantum Mechanics	1	1	9	FPO-M Physics
4PHYMA06	Theoretical Particle Physics I	1	1	9	FPO-M Physics
4PHYMA22	Theory of Condensed Matter	1	1	6	FPO-M Physics
4PHYMA25	Laser Spectroscopy	1	1	6	FPO-M Physics
4PHYMA26	Nano-Optics	1	1	6	FPO-M Physics
4PHYMA27	Experimental Methods of Quantum and Nano-Optics	1	1	6	FPO-M Physics
4PHYMA28	Quantum Theory of Light	1	1	6	FPO-M Physics
4PHYMA29	Mathematics of Quantum Mechanics	1	1	3	FPO-M Physics
4PHYMA30	Quantum Effects and Quantum Paradoxes	1	1	6	FPO-M Physics
4PHYMA31	Special Topics in Quantum and Nano-Optics	1	1	6	FPO-M Physics
4PHYMA46	Quantum Optics at the Nano-Scale	1	1	6	FPO-M Physics
4PHYMA48	Aspects of Machine Learning	1	1	6	FPO-M Physics
4PHYMA49	Quantum Thermodynamics	1	1	6	FPO-M Physics
4INFMA313	Quantum Complexity Theory	1	1	6	FPO-M Computer Science
4ETMA203	Optoelectronics	0	1	6	FPO-M Electrical Engineering
Field "Methods and Applications"					
4MATHBA10	Software lab on computer algebra	1	0	6	FPO-B Mathematics
4MATHBA30	Algebra	0	1	9	FPO-B Mathematics
4MATHBA31	Algorithmic Algebra	0	1	9	FPO-B Mathematics
4MATHBA34	Functional Analysis I	0	1	9	FPO-B Mathematics
4MATHBA37	Linear Programming	0	1	9	FPO-B Mathematics
4MATHMA11	Specialization Algebra 1	0	1	9	FPO-M Mathematics
4MATHMA21	Specialization Analysis/Modeling 1	0	1	9	FPO-M Mathematics
4MATHMA51	Specialization Numerics/Optimization 1	0	1	9	FPO-M Mathematics
4INFBA013	Machine Learning	0	1	6	FPO-B Computer Science
4INFBA302	Complexity Theory I	1	1	6	FPO-B Computer Science
4INFMA203	Statistical Learning Theory	0	1	6	FPO-M Computer Science
4INFMA204	Deep Learning	1	1	6	FPO-M Computer Science
4INFMA205	Recent Advances in Machine Learning	1	0	6	FPO-M Computer Science
4INFMA206	Convex Optimization for Computer Vision	1	1	6	FPO-M Computer Science
4INFMA313	Quantum Complexity Theory	1	1	6	FPO-M Computer Science
4ETBA008	Fundamentals of High Frequency Technology	0	1	6	FPO-B Electrical Engineering
4ETMA200	Signals and Systems I	1	1	6	FPO-M Electrical Engineering
4ETMA202	Lightwave Technology	0	1	6	FPO-M Electrical Engineering

4ETMA203	Optoelectronics	0	1	6	FPO-M Electrical Engineering
4ETMA205	High Frequency Engineering	0	1	6	FPO-M Electrical Engineering
4ETMA255	Communications and Information Security I	0	1	6	FPO-M Electrical Engineering
4ETMA257	Introduction to Compressive Sensing	0	1	6	FPO-M Electrical Engineering
4ETMA258	Selected Elements of Compressive Sensing	0	1	6	FPO-M Electrical Engineering
4ETMA357	Photonic Devices	0	1	6	FPO-M Electrical Engineering
4ETMA358	Nanotechnology	1	1	6	FPO-M Electrical Engineering
Area "Miscellaneous"					
4PHYMA09	Master's Lab (Physics Lab Course)	0	1	9	FPO-M Physics
4QSMA09	Industrial Internship	1	0	3	Annex 7

The student can apply for recognition of additional modules from the core elective courses.

Annex 5: List of core elective modules pursuant to Article 3 § 8 para. 4

Not applicable.

Annex 6: List of core elective modules pursuant to Article 4 § 8 para. 4

Not applicable.

Module Descriptions

Annex 7: Module Descriptions for Article 2

No.	4QSMA01		
Module Title	Concepts of Quantum Science		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	WS		
Language of Instruction	English		
Credit Points	6 CP		
Hours Per Week per Semester	4 hours per week per semester		
In-Class Attendance	60 h		
Self-study	120 h		
Workload	180 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours per Week per Semester**
Lecture	Concepts of Quantum Science	30	2
Exercise	Concepts of Quantum Science	15	2
Academic Work	**Format**	**Length / Scope**	
Examinations	None		
Coursework	Regular participation in the exercise and/or written test or oral test *Form and scope of the coursework will be announced no later than four weeks after the start of the course.*	90-120 min. 20-120 min.	
Qualification Objective	The students achieve an overview on different aspects of quantum science. They understand how quantum mechanical notions play a role in physics, mathematics, computer science, and engineering, and are able to develop their own interests.		
Contents	This is a series of lectures that will be given by three or four lecturers from the involved departments. Each of the lecturers will introduce one topic (over 3-4 weeks) relevant for all participating students. Possible topics are: Quantum cryptography, particle trapping, algorithmic complexity, or mathematical optimization.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: None		
Prerequisites for Awarding of CP	Successfully completed coursework		

No.	4QSMA02		
Module Title	Seminar: Quantum Science		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	SS		
Language of Instruction	English		
Credit Points	6 CP		
Hours Per Week per Semester	2 hours per week per semester		
In-Class Attendance	30 h		
Self-study	150 h		
Workload	180 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Seminar	Seminar: Quantum Science	30	2
Academic Work	**Format**		**Length / Scope**
Examinations	Seminar presentation		60-90 min.
Coursework	Regular participation *The scope of the coursework will be announced no later than four weeks after the start of the course.*		
Qualification Objective	Students learn how to prepare a seminar presentation on a selected topic using specialized research literature. They also learn how to use advanced presentation techniques.		
Contents	The topics of this seminar depend on the research topics of the involved lecturers. These include: 1. mathematical structures of quantum theory, 2. quantum information theory, 3. programming of quantum computers, 4. implementations using trapped ions, 5. quantum engineering and enabling technologies.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: Knowledge of quantum physics, such as contents of the modules 4QSMA04, 4QSMA05.		
Prerequisites for Awarding of CP	Successfully passed examination credits and coursework		

No.	4QSMA03		
Module Title	Mini Research Project		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	SS		
Language of Instruction	English		
Credit Points	9 CP		
Hours Per Week per Semester	4 hours per week per semester		
In-Class Attendance	60 h		
Self-study	210 h		
Workload	270 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Lab	Mini Research Project	10	4
Academic Work	**Format**	**Length / Scope**	
Examinations	Written report	Approx. 15 pages	
Coursework	Project Internship *The scope of the coursework will be announced no later than four weeks after the start of the course.*		
Qualification Objective	The students extend their practical skills by means of practical research that they carry out under guidance. The students learn how to use modern computer systems and/or experimental tools. A critical evaluation of the work as well as of the results is part of the report.		
Contents	This is a lab course taking place in one of the research groups. Possible topics are: 1. Programming quantum computers, 2. quantum sensing, 3. probing nonclassical light, 4. computer algebra systems, 5. data analysis of images.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: Knowledge of quantum physics, such as contents of the modules 4QSMA04, 4QSMA05.		
Prerequisites for Awarding of CP	Successfully passed examination credits and coursework		

No.	4QSMA04		
Module Title	Quantum Phenomena		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	WS		
Language of Instruction	English		
Credit Points	6		
Hours Per Week per Semester	4		
In-Class Attendance	60 h		
Self-study	120 h		
Workload	180 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Lecture	Quantum Phenomena	30	2
Exercise	Quantum Phenomena	15	2
Academic Work	**Format**		**Length / Scope**
Examinations	Written Examination or Oral Defense *Form and scope of the examination credit will be announced no later than four weeks after the start of the event.*		90-120 min. 20-40 min.
Coursework	Regular participation in the exercise and/or written test or oral test *Form and scope of the coursework will be announced no later than four weeks after the start of the event.*		90-120 min. 20-40 min.
Qualification Objective	The students will be introduced to the limits of classical physics and signatures of quantum mechanical phenomena and learn to understand and apply concepts of quantum mechanics introduced along with experimental evidence.		
Contents	Quantum effects of light: Planck's Radiation law, photons, photoelectric effect, Compton effect, Young's double slit experiment, entanglement, quantum eraser. Wave properties of particles: Matter waves and wave functions, Schrödinger equation, interference and tunnelling, time evolution. Stern-Gerlach experiment, directional quantization, superposition, measurement, eigenvalues and eigenstates, expectation value, Heisenberg's uncertainty principle. Quantum structure of atoms: Absorption and emission spectra, Franck-Hertz experiment. angular momentum, atomic structure: hydrogen atom, Zeeman effect, fine structure, hyperfine structure, electron spin resonance, emission and absorption of electromagnetic radiation, selection rules, multi-electron systems, shell model, periodic table. Quantum states of light: Coherent states, Fock states, generation of non-classical light, laser theory, experimental tests of Bell inequalities.		

Applicability in the following degree programs	MA Quantum Science
Prerequisites for Participation	Formal: None Subject: None
Prerequisites for Awarding of CP	Successfully passed examination credits and coursework

No.	4QSMA05		
Module Title	Introduction to Quantum Theory		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	WS		
Language of Instruction	English		
Credit Points	9		
Hours Per Week per Semester	6		
In-Class Attendance	90 h		
Self-study	180 h		
Workload	270 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Lecture	Introduction to Quantum Theory	30	4
Exercise	Introduction to Quantum Theory	15	2
Academic Work	**Format**		**Length / Scope**
Examinations	Written Examination or Oral Examination *Form and scope of the examination credit will be announced no later than four weeks after the start of the event.*		90-180 min. 20-40 min.
Coursework	Regular participation in the exercise and/or written test or oral test *Format and scope of the coursework will be announced no later than four weeks after the start of the course.*		90-120 min. 20-40 min.
Qualification Objective	The students understand the structure and axioms of quantum mechanics. They know the basic methods as well as some advanced theoretical tools and can apply them to solve problems in quantum information processing.		
Contents	Basic notions of quantum mechanics: states, measurements, observables, time evolution, transformations Typical problems: harmonic oscillator, one-dimensional potentials Composite systems: spin, tensor products, density matrices Typical applications: quantum key distribution, quantum metrology, quantum gates		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	None		
Prerequisites for Awarding of CP	Successfully passed examination credits and coursework		

No.	4QSMA06		
Module Title	Preparation project		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	Every semester		
Language of Instruction	English		
Credit Points	18 CP		
Hours Per Week per Semester	0 hours per week per semester		
In-Class Attendance	0 h		
Self-study	540 h		
Workload	540 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Preparation project	Preparation project		
Academic Work	**Format**	**Length / Scope**	
Examinations	None		
Coursework	Preparation for the master's thesis with final expert discussion		
Qualification Objective	The research preparation project deals with preparatory tasks. In this way, the students should demonstrate that they have acquired the specialized knowledge and methods to such an extent that they can successfully apply them to questions from the field from which the topic of the master's thesis is to originate. In this module the supervisor (and lead assessor) of the master's thesis decides about individual measures and preparatory tasks for performing the research leading to master's thesis. The preparatory task depends on the planned topic of the master's thesis. For example, the preparation may consist of literature research, participation in further (ungraded) teaching modules, or preparatory work in the lab.		
Contents	In the preparation project, the students start reading literature relevant for their master's thesis. They get used to the scientific topic of interest and learn key results from this field.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: None		
Prerequisites for Awarding of CP	Successfully completed coursework.		

No.	4QSMA07		
Module Title	Master's Thesis		
Compulsory/Core Elective	C		
Module Length	1 semester		
Frequency Offered	Every semester		
Language of Instruction	English		
Credit Points	30 CP		
Hours Per Week per Semester	0 hours per week per semester		
In-Class Attendance	0 h		
Self-study	900 h		
Workload	900 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
	Master's Thesis		
Academic Work	**Format**	**Length / Scope**	
Examinations	Master's Thesis (75%) with Colloquium (25%) (presentation with follow-on discussion, open to university community)	26 weeks, max. 120 pages 30 min. + 10-20 min.	
Coursework	None		
Qualification Objective	The students can: 1. perform an independent literature search, 2. read and understand current research literature, 3. tackle a challenging problem with scientific methods, 4. present their results in a thesis (60-120 pages), and 5. present and discuss their results in a colloquium.		
Contents	In the MSc thesis the student will tackle a current research problem with scientific methods within a given time frame. The results will be presented as a written thesis and as a colloquium followed by a discussion.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: For the degree program variant "Q," modules 4QSMA01 and 4QSMA06 as well as an additional 48 CP must be successfully completed. For the degree program variant "NQ," modules 4QSMA01, 4QSMA04, 4QSMA05, and 4QSMA06 as well as an additional 33 CP must be successfully completed. Subject: None		
Prerequisites for Awarding of CP	Successfully passed examination credits		

No.	4QSMA08		
Module Title	Research School: Quantum Science		
Compulsory/Core Elective	CE		
Module Length	1 semester		
Frequency Offered	Every semester		
Language of Instruction	English		
Credit Points	3 CP		
Hours Per Week per Semester	2 hours per week per semester		
In-Class Attendance	30 h		
Self-study	60 h		
Workload	90 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Lecture	Research School: Quantum Science	30	2
Academic Work	**Format**	**Length / Scope**	
Examinations	None		
Coursework	Participation in research school, incl. written report		
Qualification Objective	The students visit an international research school on topics relevant to quantum science. They become acquainted with research talks on an international level and learn how to discuss with other participants and researchers.		
Contents	The students visit an international research school on topics relevant to quantum science. At this school, international experts provide an overview on current research. In order to use this module for their studies, students must contact a lecturer before visiting the school in order to agree on the suitability of the school and on the report to write about it afterwards. Financial support for travel and the school is typically not provided by the University of Siegen. This module is not graded.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: Knowledge of quantum physics, such as contents of the modules 4QSMA04, 4QSMA05.		
Prerequisites for Awarding of CP	Successfully completed coursework.		

No.	4QSMA09		
Module Title	Industrial Internship		
Compulsory/Core Elective	CE		
Module Length	3 weeks		
Frequency Offered	Every semester		
Language of Instruction	Depends on type of company		
Credit Points	3 CP		
Hours Per Week per Semester			
In-Class Attendance	0 h		
Self-study	90 h		
Workload	90 h		
Teaching and Learning Forms	**and/or Courses/Module Elements**	**Group Size**	**Hours Per Week per Semester**
Industrial Internship	Industrial Internship		
Academic Work	**Format**	**Length / Scope**	
Examinations	None		
Coursework	Participation in an industrial internship incl. written report	3-10 pages	
Qualification Objective	The students work as an intern in a company working on topics relevant to quantum science. They become acquainted with applying research methods and results in an industrial and commercial context. Furthermore, they learn to work in a team of scientists as well as with employees from different areas.		
Contents	The content of the internship depends on the company. The activity of the company as well as the work of the student during the internship need to be relevant for quantum science.		
Applicability in the following degree programs	MA Quantum Science		
Prerequisites for Participation	Formal: None Subject: None		
Prerequisites for Awarding of CP	Successfully completed coursework.		