UNIVERSITY OF AMSTERDAM

FACULTY OF SCIENCE

TEACHING AND EXAMINATION REGULATIONS

PART B

ACADEMIC YEAR 2020-2021

MASTER PROGRAM

M A T H E M A T I C S

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Chapter 1 General provisions

Article B-1.1 *Definitions*

In addition to TER Part A, the following definitions are used in TER Part B:

a. Personal Education Plan: An individual study plan for the student's master programme.

b. Master Project: Compulsory internship or master thesis resulting in a written report.

c. Mastermath: a collaboration of nine Dutch universities offering Masters in mathematics.

Article B-1.2 *Degree programme information*

§1. The Master Mathematics (CROHO 66980) is offered on a full-time basis. The language for the program is English.

§2. The programme has a workload of 120 EC and is offered in collaboration with Mastermath.

§3. Students choose between a regular programme and programmes with a major or minor. Each major and minor has its specific exit qualifications (see Appendix 3).

§4. The student may choose a major or a minor from the list below (see also *Article B-4.1*).

Major (60 EC)	Minor (30 EC)
Science Communication	Teaching (in Dutch)
Science in Society	Tesla
Teaching (in Dutch)	Science for Sustainability

Article B-1.3 *Entry date*

The programme is offered starting in the first semester of an academic year (1 September) and at the start of the second semester (1 February). These entry dates ensure the curriculum can be completed within the nominal time period.

Chapter 2 Programme objectives and exit qualifications

Article B-2.1 *Program objectives*

§1. The programme aims to provide students with knowledge, abilities and insight in the field of mathematics, to enable them to work as an academic professional, or to become qualified to pursue advanced training as scientific researcher.

§2. The programme also aims at furthering the understanding of the position, role and responsibility of mathematics in science and society.

Article B-2.2 *Exit qualifications*

§1. The student graduating from the programme:

a. has a thorough theoretical and practical knowledge of mathematics, including the knowledge of other disciplines required for that purpose;
b. has insight in the development and heuristics of modern mathematics;
c. has specialist knowledge and research experience in at least one sub-area of mathematics;
d. can formulate a research plan based on a relevant problem in mathematics;
e. is able to analyse and formulate research results and to draw conclusions from them;
f. is able to write a scientific report;
g. is able to participate in discussions about mathematical problems with fellow researchers;
h. is able to consult international professional literature in the relevant sub-areas and to apply the acquired knowledge;
i. is able to apply the mathematical knowledge in a broader, multidisciplinary, context;
j. is employable in those positions in which knowledge and research skills in the field of mathematics are a prerequisite;

k. has in depth knowledge of, and insight in the social role of mathematics to make sound choices regarding one's own profession, as well as in the exertion of this profession;
l. is able to cooperate with other people, to convey knowledge to other people and to give a presentation both to discipline specialists and to a broader audience;
m. is aware of potential ethical implications of the use of mathematics and mathematical models.

§2. In addition to §1, a student completing the regular programme (see *Article B-4.1*) is able to

a. place obtained results and conclusions in the context of results obtained by other scientists;
b. carry out literature research in mathematics using various sources, and combine and enrich these with personal contributions;
c. develop a vision on the development of scientific research in the field of study.

§3. The final attainment levels of the major and minor programmes and the learning outcomes of the minor Tesla are listed in Appendix 3. See also https://tinyurl.com/ya4kkfrt.

Chapter 3 Further admission requirements

Article B-3.1 *Admission requirements*

§1. Students who have successfully completed a Bachelor's degree Wiskunde awarded by a Dutch University may be admitted.

§2. Students who have successfully completed a Bachelor's degree Beta-Gamma met Major Wiskunde, awarded by the University of Amsterdam, may be admitted.

§3. Without prejudice to the provisions of §1, the Admissions Board may grant admission to the study programme when concluding that the previous education of the candidate is equivalent to the Bachelor's degree referred to in §1.

Article B-3.2 *Pre-master's programme*

§1. Without prejudice to the provisions of *Article B-3.1* the Admissions Board may grant admission to a student whose previous education does not meet aforementioned admission requirements to the study programme, when concluding that the candidate is able to meet these admission requirements within a reasonable period of time. At the request of a candidate, and when the Admissions Board has decided additional education feasible, the Admissions Board may draw up a programme of at most 30 EC as an admission requirement, a so-called Pre-master's programme.

§2. After successful completion of this Pre-master's programme a letter of admission will be issued, exclusively for the stated Master's programme.

Article B-3.3 *Limited programme capacity*

Not applicable.

Article B-3.4 *Final deadline for registration*

A request for admission to the Master's programme starting in September must be received before June 30, 23.59 CEST for EU/EEA/Swiss students, and before January 31, 23.59 CEST for non-EU/EEA/Swiss students. For the programme starting in February, applications must be received before October 31, 23.59 CEST for EU/EEA/Swiss students and before August 31, 23.59 CEST for non-EU/EEA/Swiss students. Under exceptional circumstances, the Admissions Board may consider a request submitted after these intake dates.

Article B-3.5 *English language requirements*

§1. The proficiency requirement in English as the language of instruction can be met by the successful completion of one of the following examinations:

a. IELTS (minimal result 6.5 and at least 6 for sub-scores for listening, reading, writing, speaking);
b. TOEFL (paper-based with minimal result 580; or internet-based with minimal result 92, and

at least 22 for the sub-scores for listening, reading, writing, speaking);
c. Cambridge Advanced English: A, B or C.

The foregoing examination must have been taken within two years before the enrollment.

§2. An exemption from the English examination in §1 shall be granted to students who:

a. had previous secondary or tertiary education in one of the following English-speaking countries: Australia, Canada (English), New Zealand, Ireland, the UK or the USA;
b. hold an English-language international baccalaureate diploma;
c. possess a Bachelor's degree from a Dutch university requiring sufficient command of English;
d. passed the final examination English as part of the VWO or the ASO (Flemish) diploma.

Chapter 4 Curriculum structure

Article B-4.1 *Composition of the degree programme*

§1. Students structure their program in one of the following three ways:

a. the regular programme;
b. the programme with minor;
c. the programme with major.

The curriculum that corresponds to each of these choices is outlined in the below table.

programme components	the regular programme	programme with minor	programme with major
Master Seminar	6 EC	6 EC	6 EC
Master Project	36 EC	24 EC	24 EC
Restricted-choice electives	66 EC	48 EC	30 EC
Free -choice electives	12 EC	12 EC	
Minor or Major		30 EC	60 EC
Total EC	120 EC	120 EC	120 EC

The majors and minors are listed in *Article B-1.2*. The contents of the study programme are determined in consultation with the Master Coordinator, and laid down in a Personal Education Programme (PEP). Students then submit their PEP for approval to the Examinations Board.

§2. Students of the regular programme and students of the programme with minor choose a specialization from the below table, and follow the mentioned Master Seminar in their first year.

Acronym	Specialization	Master Seminar
A&G	Algebra and Geometry	A&G and MPH
ADS	Analysis and Dynamical Systems	ADS
MPH	Mathematical Physics	A&G and MPH
STO	Stochastics	STO

The 66EC restricted-choice electives for the regular programme and the 48EC restricted-choice electives for the programme with minor (see the table in §1) must:

a. all be selected from the complete Master Mathematics Curriculum listed in Appendix 1;
b. satisfy the additional restrictions formulated in Appendix 2.

§3. Students of the regular program and students of the regular program with minor who wish to deviate from the restrictions as in §2 may formulate an alternative Personal Education Plan, including a topic of the Master Project Mathematics. This should be done in consultation with the Master Coordinator and submitted for approval to the Examinations Board before execution.

§4. The 30 EC Minor Tesla takes place in the second semester of the second year. It has a separate intake procedure for admission and has limited capacity. The Minor Tesla requires that students have finished 48 EC of their research programme before they can participate.

§5. Students of the program with major go through a separate intake procedure for admission into the major. Each major must be combined with a 60EC research programme, and each major requires that students have completed 48EC of this research programme before they can participate. The research programme consists of the following components (see table in §1):

a. a smaller sized 24EC Master Project;
b. the 6EC Master Seminar most related to the topic of the Master Project;
c. a least 30EC elective components related to the topic of the Master Project.

The elective components must be selected from Appendix 1 in consultation with the Master Coordinator and approved by the Examinations Board before commencing. They do not have to satisfy the requirements detailed in Appendix 2 for the specializations from §2.

§6. The 60EC Major Teaching offered by the Interfacultaire Lerarenopleidingen (ILO) results in the first-degree teaching competency (Dutch: eerstegraads bevoegdheid). Students who already have the second-degree teaching competency (tweedegraads bevoegdheid), for example by having completed the Educatieve Minor in the Bachelor, can obtain the first-degree teaching competency by following a reduced 30EC program at ILO. The program should then be implemented as a program with minor (see §1-4). An alternative implementation may be possible, but only after consultation with both Major- and Master Coordinator and approval by the Examinations Board.

Article B-4.2 *Compulsory units of study*

§1. The Master Seminar is compulsory. Content, format, and assessment criteria of the Master Seminar in Algebra, Geometry and Mathematical Physics, the Master Seminar in Stochastics, and the Master Seminar in Analysis and Dynamical Systems are described in the Course Catalogue.

§2. Measure Theoretic Probability is a compulsory course for the specialization Stochastics.

§3. The Master Project Mathematics is compulsory.

a. The Master Project Mathematics is conducted under the supervision of an examiner, and consists of a thesis, a midterm presentation in the relevant Master Seminar, and a final presentation.

b. At the end of the Master Project Mathematics the examiner verifies on the basis of the assessment criteria, whether the student has sufficiently achieved the exit qualifications.

The assessment criteria are the:
1. quality and content of the written thesis (50%);
2. student's attitude and execution of the project (35%);
3. midterm presentation (5%);
4. final presentation (10%).

c. Concerning the assessment of the Master Project Mathematics:
1. a second examiner will act as an independent reviewer;
2. the coordinator of the Master Seminar will assess the midterm presentation;
3. the final presentation will be attended by the examiner and the second reviewer;
4. the final grade will be determined by the examiner and the second reviewer;
5. a member of the Examinations Board will supervise the assessment procedure.

Article B-4.3 *Practical exercise* Not applicable.

Article B-4.4 *Electives*

§1. The restricted-choice elective courses are all listed in Appendix 1.

§2. Course components successfully completed elsewhere or that are not included in the list of restricted-choice elective components may be included in the student's Personal Education Plan

(PEP) only subject to prior permission from the Examinations Board. Such course components:

a. have to be offered by an accredited university or institute that is of a comparable level;
b. must be relevant to the programme;
c. must have been completed during the period that the student is enrolled in the programme.

§3. In terms of content, restricted-choice elective components must not show too much similarity to other components of the student's PEP. The acceptable degree of similarity is to be decided by the Examinations Board.

§4. The contents and assessment method of Reading Course Mathematics (6EC) and Reading Course (3EC) needs to be approved by the Examinations Board prior to the start of the course. The examiner of the reading course sends in a request for approval to the Examinations Board, containing a short description of the content, the reading material, and the assessment procedure.

§5. The restricted-choice elective course Quantum in Business and Society (3EC) is a skills course.

§6. The free-choice elective components:

a. must not show too much overlapping content with other components in student's PEP;
b. may in exceptional cases be at Bachelor level.

They will only be accepted as part of PEP if the Examinations Board has given its prior approval.

Article B-4.5 *Free curriculum*

§1. Subject to certain conditions, students have the option to compile a curriculum of their own choice, which deviates from the curricula stipulated by the degree programme.

§2. The composition of this curriculum must first be approved by the Examinations Board.

§3. It must possess at least the extent, breadth and depth of the regular programme described in *Article B-4.1* and must be in line with the learning outcomes of the degree programme as formulated in *Article B-2.2*. At least 60EC of the proposed curriculum has to consist of components of the regular programme, and must include a Master Seminar and the Master Project Mathematics.

Article B-4.6 *Sequence of examinations*

§1. Participation in a restricted-choice elective course may require particular mathematical prerequisites. The prerequisites for each course are listed in the Course Catalogue.

§2. The Master Project in the regular programme may only be commenced if the other compulsory course components and the restricted-choice elective components have been completed.

Article B-4.7 *Further conditions for registration for examinations* Not applicable.

Article B-4.8 *Further conditions for examination opportunities* Not applicable.

Article B-4.9 *Participation practical training and tutorials* Not applicable.

Article B-4.10 *Further conditions for exemption*

§1 A maximum of 60 EC of the curriculum may be obtained through granted exemptions.

Article B-4.11 *Validity period of results* Not applicable.

Article B-4.12 *Degree*

A student who passes the final examination of a programme is awarded a Master of Science degree. The name of the degree awarded is stated on the diploma.

Article B-4.13 *Mastermath*

Students taking courses as part of Mastermath may also be subject to rules and regulations that have been agreed on nationally. See the General Rules & Guidelines at http://elo.mastermath.nl.

Article B-4.14 *Double Degree Programme Mathematics and Physics & Astronomy*

§1. A student can be awarded both the Master's degrees Mathematics and Physics & Astronomy with track Theoretical Physics after successfully completing the programme described below. The student must have been admitted to both Master programmes separately.

§2. The total study load of the Double Degree Programme is at least 180 EC:

Double Degree Program Mathematics and Physics & Astronomy	180EC
Compulsory components	46EC
Restricted-choice electives from Physics & Astronomy	12EC
Restricted-choice electives from Mathematics	38EC
Integrated Research Project Mathematics and Theoretical Physics	72EC
Free-choice elective courses	12EC

§3. The 46EC compulsory components are:

Compulsory components:	46EC
Master Seminar in Algebra, Geometry and Mathematical Physics	6EC
Student Seminar Theoretical Physics	6EC
Differential Geometry	8EC
Lie Groups	8EC
Quantum Field Theory	6EC
Statistical Physics & Condensed Matter Theory 1	6EC
Topology in Physics	6EC

§4. The 12 EC restricted-choice elective courses from the Master Physics & Astronomy must include at least 6 EC from the track Theoretical Physics. The courses Mathematical Methods and Group Theory cannot be taken as part of these 12 EC. See the Teaching and Examination Regulations of the Master Physics & Astronomy for the list of courses of the Master Physics & Astronomy, and the sublist of ourses from the track Theoretical Physics.

§5. The 38EC restricted-choice elective courses from the Master Mathematics include at least one of the courses Algebraic Topology 1, Algebraic Geometry 1 and Riemann Surfaces, and at least two restricted-choice electives from the lists of advanced/specialized courses of the specialization directions Algebra & Geometry and Mathematical Physics (see Appendix 2). The complete list of restricted-choice elective courses of the Master Mathematics can be found in Appendix 1.

§6. The Integrate Research Project Mathematics and Theoretical Physics must be supervised by examiners from both the Master's programmes. They must assess the project as a pass according to the standards and procedures for assessment of the Master Project Mathematics and the Research Project Physics and Astronomy.

§7. The Integrate Research Project Mathematics and Theoretical Physics can be replaced by both the two separate projects: Master Project Mathematics (36 EC), and Research Project Physics and Astronomy (60EC). In this case the total load of the programme must be at least 192 EC.

Article B-4.15 *Double Degree Programme (Mathematics and other two-year programmes)*

In case a student combines two Master programmes and their components other than mentioned in *Articles B-4.14* and *Article B-4.16*, the following requirements must be met in order to be awarded two Master's degrees:

§1. The total programme of the candidate should amount to at least 180 EC credits.

§2. The two master programmes may not show too much similarity.
§3. The student's work for the programme (lectures, research work, etc.) must be of such a standard that all the exit qualifications of each of the two programmes are met.
§4. The student must have conducted separate research work for both Master's degrees. This may consist of two separate research projects with supervisors from the respective study programmes. In the case of an integrated research project, this must be supervised by examiners from the two Master's programmes. The project must be assessed as a pass by both examiners according to the standard and procedures for Master project assessment of the respective master degrees. The total number of credits given for an integrated research project is 3/4 of the sum of the credits given for two independent research projects.
§5. In addition to §1-4, the other study programme may impose further requirements.
§6. The Examinations Boards of both study programmes must approve the student's double Master's programme before the student commences with the double Master's programme.

Article B-4.16 *Double Degree Programme Mathematics and Econometrics*

A student can be awarded both the Master's degrees Mathematics and Econometics after successfully completing the programme described below. The student must have been admitted to both Master programmes separately.

§1. The total study load of the Double Degree Programme is at least 150 EC.
§2. The student's work for the Master's programme (lectures, research work etc.) is of such a standard that all exit qualifications of each of the two programmes have been met. The specific programme requirements for double degree students are described in the document Double degree programmes in Econometrics and Mathematics/SFM, which is available at the study guide pages of the master programmes. See https://tinyurl.com/y94op57m.
§3. The candidate has conducted an integrated research project Master Project Econometrics and Mathematics (36 EC), replacing Master Project Mathematics. This must be supervised by examiners and independent second reviewers from each of the two Master's programmes. The project must be assessed as a pass by the examiners according to the standards and procedures for Master project assessment of the respective master degrees.
§4. The Examinations Boards of both study programmes must approve the student's double Master's programme before the student commences with the double Master's programme.

Chapter 5 Academic student counseling

Article B-5.1 *Academic student counseling*

The programme's academic student counseling consists of Master Coordinator and Study Adviser.

Chapter 6 Teaching evaluation

Article B-6.1 *Teaching evaluation*

Teaching evaluation takes place via the UvA Q course evaluation system, by peer review of exams and resit, and quality assessment by the Program Committee and by the Examinations Board.

Chapter 7 Transitional and final provisions

Article B-7.1 *Amendments and periodic review*

§1. Amendments to Section B of the Teaching and Examination Regulations shall be adopted by the dean after taking advice from the relevant Programme Committee. A copy of the advice will be sent to the authorised representative advisory body.

§2. Amendments to Section B of the Teaching and Examination Regulations shall require the approval of the Faculty representative advisory body for components that do not relate to the

subject matter of Section 7.13, subsection 2, under a−g, as well as subsection 4, of the WHW. Components related to the subjects of Section 7.13, paragraph 2, under (v) must be submitted to the Faculty representative advisory body for advice.

§3. Amendments to the Teaching and Examination Regulations may only pertain to an academic year that is already in progress if it can be shown that this does not harm student's interests.

Article B-7.2 *Transitional provisions*

§1. The following course components of the past academic year have been canceled:

Canceled course components from the academic year 2019-2010
Advanced Combinatorics: zeros of graph polynomials, Markov chains and algorithms
Advanced Topics in Stochastic Analysis
Blowing Ups and Deformations: an Introduction to the Theory of Singularities
Calculus of Variations
Complex Dynamical Systems
Computational Complexity
Diophantine Approximation
Introduction to Numerical Bifurcation Analysis of ODEs and Maps
Mathematical Biology
Mathematical Optimisation
Model Theory
Modular Forms
Numerical Methods for Stationary PDEs
Percolation: from Introduction to Frontiers of Current Research
Poisson Geometry
Probabilistic and Extremal Combinatorics
Statistics for Life Sciences
Statistics for Stochastic Processes
Statistical Theory for High-and Infinite-Dimensional Systems
Topological Data Analysis
Topology of Algebraic Varieties

§2. The following three courses have been renamed. Each of these three courses can only appear under one of its two names in student's Personal Education Plan.

previous name	new name as of 2020-2021
Category Theory and Topos Theory	Category Theory
Entrepreneurship in Data Science	Entrepreneurship in Analytics and AI
Stochastic Optimization	Dynamic Programming and Reinforcement Learning

§3. These regulations apply to anyone enrolled in the programme. However, regarding the curriculum requirements as stated in *Article B-4*, the student may make an appeal to the regulations of the academic year of the student's enrollment in the programme.

Article B-7.3 *Publication*

§1. The dean shall ensure a fitting publication of part A and B of these Regulations and the rules and guideline referred to in the Act.

§2. They can be accessed at the website of the Faculty of Science and the UvA Course Catalogue.

Article B-7.4 *Effective date*

These Regulations enter into force with effect from 1 September, 2020.
Thus drawn up by the Dean of the Faculty of Science on ?? August, 2020.

Appendix 1 Description of the content and study load of the components

All courses have lectures and/or tutorials and are assessed by a written or oral exam, apart from the 3EC and 6EC Reading Courses, which are a literature study with alternative examination.

Course Name	Code	EC	Period
Additive Combinatorics	5334ADCO8Y	8	4,5
Advanced Algebraic Geometry: Rational Points	5334AAGR8Y	8	1,2
Advanced Linear Programming	53348ALP6Y	6	4,5
Advanced Machine Learning	53348ADM6Y	6	1,2
Algebraic Geometry 1	53341ALG8Y	8	1,2
Algebraic Geometry 2	53342ALG8Y	8	4,5
Algebraic Methods in Combinatorics	5334AMIC8Y	8	4,5
Algebraic Number Theory	53348ANT8Y	8	1,2
Algebraic Topology 1	53341ALT8Y	8	1,2
Algebraic Topology 2	53342ALT8Y	8	4,5
Algorithms Beyond the Worst Case	5334ABTW8Y	8	1,2
Analytic Number Theory	5334ANNT8Y	8	1,2
Applied Finite Elements	53348AFE6Y	6	4,5
Asymptotic Statistics	5374ASST8Y	8	1,2
Bayesian Statistics	5334BAST8Y	8	4,5
Category Theory	5314CTTT8Y	8	
Causality	5334CAUS6Y	6	4,5
Coding and Cryptography	53348CCR6Y	6	4,5
Coding Theory	53348CTH8Y	8	4,5
Commutative Algebra	53348COA8Y	8	1,2
Complex Networks	5374CONE8Y	8	4,5
Computability Theory	53348COT8Y	8	1,2
Continuous Optimization	53348COP6Y	6	1,2
Cryptology	5334CRYP5Y	5	1,2
Data-driven Decision Making in Operations Research	5334DDDM6Y	6	4,5
Deformation Quantization, Graph Complex & Number Theory	5334DQGC8Y	8	1,2
Differential Geometry	53348DIG8Y	8	1,2
Discrete Optimization	53348DOP6Y	6	1,2
Dynamical Systems	53348DYS8Y	8	1,2
Dynamic Programming and Reinforcement Learning	53348DPR6Y	6	1,2
Elliptic Curves	53348ELC8Y	8	4,5
Entrepreneurship in Analytics and AI	53348EIA6Y	6	4,5
Ergodic Theory	53348ERT8Y	8	1,2
Forensic Probability and Statistics	5334FOPS8Y	8	1,2
Functional Analysis	53348FUA8Y	8	1,2
History and Philosophy of Mathematics	5334HIPM8Y	8	4,5
Infinity-Categories	5334INCA6Y	6	1,2
Interacting Particle Systems: Theory & Applications	5334IPST8Y	8	1,2
Interest Rate Models	5374INRM6Y	6	1,2
Inverse Problems in Imaging	5334IPII6Y	6	4,5
Lie Algebras	5334LIAL8Y	8	4,5
Lie Groups	53348LIG8Y	8	1,2
Machine Learning Theory	5334MALT8Y	8	4,5
Mathematical Neuroscience	5334MANE8Y	8	4,5
Measure Theoretic Probability	5374METP8Y	8	1,2
Mirror Symmetry	5324MISY6Y	6	4,5
Nonparametric Statistics	5334NOST6Y	6	4,5
Numerical Bifurcation Analysis of Large-Scale Systems	53348NBA8Y	8	4,5

Appendix 1 Description of the content and study load of the components

Course Name	Code	EC	Period
Numerical Linear Algebra	53348NLA8Y	8	1,2
Numerical Methods for Time-Dependent PDEs	53348NMT8Y	8	4,5
Operator Algebras	53348OPA8Y	8	4,5
Optimisation of Business Processes	53348OPB6Y	6	4,5
Parallel Algorithms	53348PAA8Y	8	1,2
Partial Differential Equations	53348PAD8Y	8	1,2
Portfolio Theory	5374POTS6Y	6	1,2
Quantum Computing	5334QUCO8Y	8	4,5
Quantum in Business and Society	5354QIBS3Y	3	6
Quantum Field Theory	5354QUFT6Y	6	2
Quantum Information Theory	5334QUIT8Y	8	4,5
Queueing Theory	53748QUT6Y	6	4,5
Queues and Levy Fluctuation Theory	5334QLFT6Y	6	4,5
Quivers	5334QUIV6Y	6	1,2
Reading Course	53342RCM6Y	3	1,2,3,4,5,6
Reading course Mathematics	5334RECM6Y	6	1,2,3,4,5,6
Riemann Surfaces	53348RIS8Y	8	4,5
Scheduling	53748SCH6Y	6	4,5
Selected Areas in Cryptology	5334SAIC8Y	8	4,5
Set Theory	5314SETH8Y	8	1,2
Simulation Methods in Statistics	5374SIMS6Y	6	1,2
Statistical Models	53348STM6Y	6	1,2
Statistical Physics & Condensed Matter Theory I	53541SPC6Y	6	1
Statistics for Networks	53748STF6Y	6	4,5
Stochastic Integration	5374STIN8Y	8	4,5
Stochastic Networks	5334STNE6Y	6	1,2
Stochastic Processes	53748STP8Y	8	4,5
Stochastic Processes for Finance	53748SPF6Y	6	1,2
Stochastic Simulation	5334STSI6Y	6	1,2
String Theory	5354STTH6Y	6	5
Symplectic Geometry	53248SYG8Y	8	4,5
Systems and Control	53348SYC6Y	6	1,2
Time Series	53748TIS8Y	8	4,5
Topics in Number Theory	5334TINT6Y	6	4,5
Topology in Physics	5354TOIP6Y	6	4,5
Topos Theory	5334TOTH8Y	8	4,5
Toric Varieties	5334TOVA6Y	6	4,5
Uncertainty Quantification & Data Assimilation	5334UQDA6Y	6	1,2
Wavelets	5334WAVE6Y	6	1,2
Master Seminars:			
Algebra, Geometry & Math Physics	5334MSIA6Y	6	1,2,3,4,5,6
Analysis and Dynamical Systems	5334MSAD6Y	6	1,2,3,4,5,6
Stochastics	5334MSIS6Y	6	1,2,3,4,5,6
Master Projects:			
Mathematics	5334MPM36Y	36	1,2,3,4,5,6
Mathematics (with Major or Minor)	5334MPM36Y	24	1,2,3,4,5,6
Mathematics & Theoretical Physics	5334MPM72Y	72	1,2,3,4,5,6
Mathematics & Econometrics		36	1,2,3,4,5,6

The Master Seminars have the format of lectures and student presentations. The latter are assessed to determine the grade. The Master Projects are assessed as described in *Article B-4.2, §3*.

Appendix 2 Restrictions on the restricted-choice electives

Algebra and Geometry	
choose 3 basic courses:	and 2 advanced/specialized:
Additive Combinatorics Algebraic Geometry 1 Algebraic Number Theory Algebraic Topology 1 Commutative Algebra Differential Geometry Lie Algebras Lie Groups Quivers Riemann Surfaces	Advanced Algebraic Geometry Algebraic Methods in Combinatorics Algebraic Geometry 2 Algebraic Topology 2 Elliptic Curves Mirror Symmetry Selected Areas in Cryptology Symplectic Geometry Toric Varieties

Analysis and Dynamical Systems	
choose 3 basic courses:	and 2 advanced/specialized:
Differential Geometry Dynamical Systems Functional Analysis Numerical Linear Algebra Numerical Methods for Time-dependent PDEs Partial Differential Equations Uncertainty Quantification and Data Assimilation Wavelets	Inverse Problems in Imaging Numerical Bifurcation Analysis of Large-Scale Systems Operator Algebras Parallel Algorithms Quantum Computing Quantum Information Theory Symplectic Geometry

Mathematical Physics		
choose 3 basic courses:	and 2 advanced/specialized:	and 1 from physics:
Algebraic Geometry 1 Algebraic Topology 1 Differential Geometry Functional Analysis Lie Algebras Lie Groups Riemann Surfaces Topology in Physics	Algebraic Geometry 2 Algebraic Topology 2 Mirror Symmetry Operator Algebras Quantum Computing Quantum Information Theory Symplectic Geometry	Quantum Field Theory Statistical Physics and Condensed Matter Theory I String Theory

Stochastics	compulsory course: Measure Theoretic Probability	
choose 1 course:	and 2 basic courses:	and 2 advanced/specialized:
Asymptotic Statistics Queueing Theory Stochastic Integration	Causality Ergodic Theory Forensic Probability and Statistics Functional Analysis Machine Learning Theory Simulation Methods in Statistics Stochastic Networks Stochastic Processes Stochastic Simulation	Complex Networks Data-driven Decision Making in Operations Research Interacting Particle Systems: Theory and Applications Interest Rate Models Nonparametric Statistics Portfolio Theory Queues and Lévy Fluctuation Theory Bayesian Statistics Uncertainty Quantification and Data Assimilation

Appendix 3 A. Final attainment levels of the major Teaching (in Dutch)

§1. De bekwaamheidseisen Leraar Voorbereidend Hoger Onderwijs zijn, naast de voor alle wo-masteropleidingen geldende Dublin-descriptoren en algemene wettelijke eisen, richtinggevend voor de doelstellingen en eindtermen van de lerarenopleidingen Voorbereidend Hoger Onderwijs. Deze bekwaamheidseisen zijn vastgelegd in de Wet op het voortgezet onderwijs (artikel 36 e.v.) en het Besluit bekwaamheidseisen onderwijspersoneel (zie het 'Besluit bekwaamheidseisen onderwijspersoneel' (http://wetten.overheid.nl/BWBR0018692) en 'Besluit van 16 maart 2017 tot wijziging van het Besluit bekwaamheidseisen onderwijspersoneel en het Besluit bekwaamheidseisen onderwijspersoneel BES in verband met de herijking van de bekwaamheidseisen voor leraren en docenten' (https://zoek.officielebekendmakingen.nl/stb-2017-148.html).

De eindtermen zijn geordend in twee categorien:

a. Eindtermen 1, 2, 3:

deze hebben rechtstreeks te maken met de kern van het beroep: het onderwijsleerproces en het leren van leerlingen, te weten de vakinhoudelijke, vakdidactische en pedagogische bekwaamheid;

b. Eindtermen 4 en 5:

deze hebben betrekking op de meer algemene aspecten van professioneel handelen ten dienste van die kern van het beroep: te weten samenwerking met collega's en de omgeving van de school en met reflectie en persoonlijke en professionele ontwikkeling.

De opleiding draagt er zorg voor dat de afgestudeerde Leraar VHO in ieder geval:

1. aantoonbaar beschikt over vakinhoudelijke kennis en vaardigheden die het wo-bachelorniveau overstijgen dan wel verdiepen, en dus:

a. de inhoud van vak beheerst / boven de leerstof staat;
b. daardoor de leerstof, voor het schooltype waarin de leraar werkzaam is, zo kan samenstellen, kiezen of bewerken dat de leerlingen die kunnen leren;
c. vanuit vakinhoudelijke expertise verbanden kan leggen met het dagelijks leven, met werk en met wetenschap en het onderwijs betekenisvol kan maken voor de leerlingen;
d. daarmee kan bijdragen aan de algemene vorming van de leerlingen.

2. aantoonbaar beschikt over vakdidactische kennis en vaardigheden, en dus:

a. de vakinhoud weet te vertalen in leerplannen of leertrajecten en dat doet op een professionele, ontwikkelingsgerichte werkwijze;
b. de vakinhoud leerbaar maakt voor en afstemt op het niveau en kenmerken van de leerlingen, daarbij doelmatig gebruikmakend van (digitale) beschikbare leermiddelen;
c. het onderwijs kan ontwikkelen en evalueren;
d. het onderwijs doelmatig kan uitvoeren en het leren van leerlingen kan organiseren;
e. de vak inhoud/didactiek afstemt met de collega's op school en laat aansluiten bij de visie en missie van de school.

3. aantoonbaar beschikt over pedagogische kennis en vaardigheden, en dus:

a. de ontwikkeling van leerlingen volgt in hun leren en gedrag en daarop het handelen afstemt;
b. bijdraagt aan de sociaal-emotionele en morele ontwikkeling van de leerlingen;
c. bijdraagt aan de burgerschapsvorming en de ontwikkeling van de leerling tot een zelfstandige en verantwoordelijke volwassene;
d. met een professionele, ontwikkelingsgerichte werkwijze en in samenwerking met collega's een veilig, ondersteunend en stimulerend leerklimaat voor leerlingen kan realiseren;
e. in staat is om oordelen te formuleren, rekening houdend met de sociaal-maatschappelijke en ethische verantwoordelijkheden die horen bij het beroep

4. aantoonbaar reflecteert ten behoeve van persoonlijke en professionele ontwikkeling, en dus:

a. in staat is kritisch te reflecteren op alle aspecten die met zijn/haar persoonlijkheid, motivatie, attitudes, verwachtingen en cognities te maken hebben (die onder meer tot uiting komen in het pedagogisch handelen) en feedback hieromtrent ter harte te nemen

b. op onderzoeksmatige wijze de (eigen) onderwijspraktijk verbetert en blijft ontwikkelen;
c. in staat is (vak)kennis en -kunde actueel te houden;
d. in staat is een eigen positie te bepalen t.a.v. de missie en visie van de school en bereid een constructieve bijdrage te leveren aan de ontwikkeling van het vak/het onderwijs in de school.

5. aantoonbaar samenwerkt en communiceert met collega's en omgeving, en dus:

a. het pedagogisch handelen kan afstemmen met collega's en met anderen die voor de ontwikkeling van de leerling verantwoordelijk zijn;
b. de ontwikkeling van het vak/curriculum in de school kan afstemmen met collega's en met anderen die voor de ontwikkeling van de leerling verantwoordelijk zijn.

§2. Onverminderd het bepaalde in §1 heeft afgestudeerde van afstudeerrichting Biologie een gedegen vakinhoudelijke kennis van en inzicht in het vakgebied en de vakdidactiek van Biologie en kan op basis daarvan aantrekkelijke, effectieve en efficiënte leeractiviteiten ontwerpen, uitvoeren, begeleiden en evalueren voor het schoolvak Biologie in de onder- en/of bovenbouw.

§3. Onverminderd het bepaalde in §1 heeft afgestudeerde van afstudeerrichting Natuurkunde een gedegen vakinhoudelijke kennis van en inzicht in het vakgebied en de vakdidactiek van Natuurkunde en kan op basis daarvan aantrekkelijke, effectieve en efficiënte leeractiviteiten ontwerpen, uitvoeren, begeleiden en evalueren voor het schoolvak Natuurkunde in de onder- en/of bovenbouw.

§4. Onverminderd het bepaalde in §1 heeft afgestudeerde van afstudeerrichting Scheikunde een gedegen vakinhoudelijke kennis van en inzicht in het vakgebied en de vakdidactiek van Scheikunde en kan op basis daarvan aantrekkelijke, effectieve en efficiënte leeractiviteiten ontwerpen, uitvoeren, begeleiden en evalueren voor het schoolvak Scheikunde in de onder- en/of bovenbouw.

§5. Onverminderd het bepaalde in §1 heeft de afgestudeerde van afstudeerrichting Wiskunde een gedegen vakinhoudelijke kennis van en inzicht in het vakgebied en de vakdidactiek van Wiskunde en kan op basis daarvan aantrekkelijke, effectieve en efficiënte leeractiviteiten ontwerpen, uitvoeren, begeleiden en evalueren voor het schoolvak Wiskunde in onder- en/of bovenbouw.

§6. Onverminderd het bepaalde in §1 heeft afgestudeerde van afstudeerrichting Aardrijkskunde een gedegen vakinhoudelijke kennis van en inzicht in het vakgebied en de vakdidactiek van Aardrijkskunde en kan op basis daarvan aantrekkelijke, effectieve en efficiënte leeractiviteiten ontwerpen, uitvoeren, begeleiden en evalueren voor het vak Aardrijkskunde in de onder- en/of bovenbouw.

B. Final attainment levels of the major Science Communication

The master graduate possesses an academic attitude, skills and competences to operate at the interface of science and society aiming to contribute to a fruitful science-society dialogue. This means that the master graduate has the following focus:

a. Understanding the dynamic relationship between science and society;
b. Translating information from the natural sciences to society and vice versa;
c. Shaping the dialogue between science and society.

Graduates have the following knowledge:

§1. Knowledge of and insight into the relevant concepts and theories in the field of science communication, sociology, communication science, philosophy and science & technology studies in relation to the natural sciences;

§2. Familiarity with scientific journals in the field of science communication and science & technology studies, as well as familiarity with a variety of popular-scientific media;

§3. Insight into the nature and course of interpersonal and group communication processes relevant to the formal and informal dialogue between science and society;

§4. Insight into relevant concepts and theories for effective communication and collaboration in relation to diverse science-society interactions;

§5. Insight into the popularization of the natural sciences in various media;

§6. Insight into the roles and responsibilities of museums in science communication.

Graduates have the following skills:

§1. Independently acquire, analyze and evaluate relevant information in a variety of scientific disciplines, by conducting literature study and empirical research;

§2. Communicate and collaborate effectively with diverse professionals of scientific and nonscientific disciplines as well as lay citizens;

§3. Design and facilitate interactive processes in relation to the science-society dialogue;

§4. Translate information from various natural science disciplines into more generally accessible language and formats;

§5. Produce popular-scientific media output concerning developments in the natural sciences, aimed at a variety of publics;

§6. Contribute to the design of museum exhibitions from the perspective of scientific content management and science communication theory;

§7. Contribute intrinsically to the societal discussion of developments in science and technology

C Final attainment levels of the major Science in Society

Dublin descriptor 1 *Knowledge and understanding*

The graduate has theoretical and practical knowledge of management, policy analysis and entrepreneurship. The graduate has insight into:

§1. the various relevant disciplines in the social and behavioural sciences. More specifically the student acquires insight into:
a. concepts and theories in the field of policy science, management studies, and entrepreneurship;
b. the relation of these gamma sciences to the beta sciences.

§2. concepts and the latest theories, research methodologies, analytical models and important research questions related to interdisciplinary research for addressing societal problems;

§3. and has knowledge of concepts and theories for effective communication and collaboration.

Dublin descriptor 2 *Applying knowledge and understanding*

The graduate is experienced in carrying out interdisciplinary research, in applying techniques specific to the subject area and in applying scientific knowledge to societal problems. The graduate:

§1. can integrate knowledge from the beta and gamma sciences, and from science and practice;

§2. can apply scientific knowledge to formulate solutions to societal problems and assess them for appropriateness and societal relevance;

§3. adopts an appropriate attitude towards the correct and unbiased use and presentation of data.

Dublin descriptor 3 *Making judgments*

The graduate is able to independently and critically judge information. The graduate is able to:

§1. independently acquire information in relevant scientific areas through a literature review and by conducting empirical research, as well as evaluate such information critically;

§2. select and order information, distinguish essentials from trivialities, and recognize connections;

§3. formulate personal learning objectives and critically evaluate own performance, both introspectively and in discussion with others.

Dublin descriptor 4 *Communication*

The graduate is able to transfer knowledge and skills related to his/her subject area to other people and to adequately reply to questions and problems posed within society. The graduate:

§1. has acquired skills to report orally and in writing on research results in English;

§2. has the ability to communicate research conclusions, and the knowledge and rationale underpinning them, to specialist audiences and non-specialist audiences clearly and unambiguously;

§3. can collaborate with researchers from various scientific disciplines;

§4. can contribute to scientific discussions about plans, results and consequences of research.

Dublin descriptor 5 *Learning skills*

The graduate has developed learning skills that enable him/her to continue with self-education and development within the subject area. The graduate:

§1. has acquired skills to develop a research plan, giving details of the problem statement, objectives, research questions, research approach, research methods, and planning;

§2. is familiar with the general scientific journals, such as Nature and Science, and with journals in the specialisation, such as Research Policy, Health Policy, Science, Technology & Human Values, Social Science & Medicine, and International Journal on Technology Management;

§3. has the learning skills to allow him/her to continue to study in a manner that may be largely self- directed or autonomous (life-long learning).

D. Final attainment levels of the minor Science & Sustainability

After completing the Minor Science for Sustainability, students have:

1. awareness of the interdependence of the global natural system, the social system and the human system as well as of the importance of the coherence that is required between them to produce effective, science-based sustainable solutions;
2. developed a view on complex sustainability issues while maintaining a clear focus on one specific disciplinary domain, in which they develop further scientific knowledge and expertise;
3. learned how sustainable solutions can be realized via system innovations and transition management;
4. become acquainted with an interdisciplinary approach in developing sustainable, science-based solutions for urgent societal challenges, including their economic and policy aspects;
5. learned to work collaboratively in an interdisciplinary student project.

E. Learning objectives of the minor Tesla

By completing the Tesla Minor the graduate is fit to start a career in demanding environments which require abilities to utilize the disciplinary science background in research, corporate, civil society, governmental and advisory work environments.

All learning objectives fall into at least one of the following categories:

1. Information processing;
2. Teamwork;
3. Project Work;
4. Communication;
5. Self-reflection.

More information on the minor Tesla can be found in the study guide: http://www.teslaminor.nl

F. Final attainment levels of the minor Educatie

§1 De bekwaamheidseisen Leraar Voorbereidend Hoger Onderwijs zijn, naast de voor alle wo-bacheloropleidingen geldende Dublin-descriptoren en algemene wettelijke eisen, richtinggevend voor de doelstellingen en eindtermen van de minor Educatie en Educatieve module. Deze bekwaamheidseisen zijn vastgelegd in de Wet op het voortgezet onderwijs (artikel 36 e.v.) en het Besluit bekwaamheidseisen onderwijspersoneel (zie Besluit bekwaamheidseisen onderwijspersoneel (http://wetten.overheid.nl/BWBR0018692/2017-08-01) en Besluit van 16 maart 2017 tot wijziging van het Besluit bekwaamheidseisen onderwijspersoneel en het Besluit bekwaamheidseisen

onderwijspersoneel BES in verband met de herijking van de bekwaamheidseisen voor leraren en docenten (https://zoek.officielebekendmakingen.nl/stb-2017-148.html). De eindtermen zijn toegespitst op de onderwijssector waarvoor de minor Educatie of Educatieve module opleidt en waarop de bevoegdheid die er sinds 2009 aan verbonden is betrekking heeft: de theoretische leerweg in het vmbo en de eerste drie klassen van havo en vwo.

De eindtermen zijn geordend in twee categorien:

a. Eindtermen 1, 2, 3:

deze hebben rechtstreeks te maken met de kern van het beroep: het onderwijsleerproces en het leren van leerlingen, te weten de vakinhoudelijke, vakdidactische en pedagogische bekwaamheid.

b. Eindtermen 4 en 5:

deze hebben betrekking op meer algemene aspecten van professioneel handelen ten dienste van die kern van het beroep: te weten samenwerking met collega's en de omgeving van de school en met reflectie en persoonlijke en professionele ontwikkeling.

De opleiding draagt er zorg voor dat de afgestudeerde Leraar VHO met een beperkte tweedegraads bevoegdheid in ieder geval:

1. aantoonbaar beschikt over vakinhoudelijke kennis en vaardigheden die verondersteld mogen worden op wo-bachelorniveau, en dus:

a. de inhoud van het schoolvak in de onderbouw beheerst;
b. daardoor de leerstof, voor het schooltype waarin de leraar werkzaam is, zo kan samenstellen, kiezen of bewerken dat de leerlingen die kunnen leren;
c. vanuit vakinhoudelijke expertise verbanden kan leggen met het dagelijks leven, en het onderwijs betekenisvol kan maken voor de leerlingen;
d. daarmee kan bijdragen aan de algemene vorming van de leerlingen

2. aantoonbaar beschikt over vakdidactische kennis en vaardigheden, en dus:

a. vakinhoud weet te vertalen in lessenreeksen en dat doet op een ontwikkelingsgerichte werkwijze;
b. vakinhoud leerbaar maakt voor de leerlingen, daarbij doelmatig gebruikmakend van (digitale) beschikbare leermiddelen;
c. het onderwijs kan ontwikkelen en evalueren;
d. het onderwijs doelmatig kan uitvoeren;
e. de vak inhoud/didactiek afstemt met collega's.

3. aantoonbaar beschikt over pedagogische kennis en vaardigheden, en dus

a. het handelen af kan stemmen op de leerlingen;
b. zicht heeft op de sociaal-emotionele en morele ontwikkeling van de leerlingen;
c. bijdraagt aan burgerschapsvorming;
d. in samenwerking met collega's een veilig, ondersteunend en stimulerend leerklimaat voor leerlingen kan realiseren;

4. aantoonbaar reflecteert ten behoeve van persoonlijke en professionele ontwikkeling, en dus:

a. in staat is kritisch te reflecteren op alle aspecten die met zijn/haar persoonlijkheid, motivatie, attitudes, verwachtingen en cognities te maken hebben (die onder meer tot uiting komen in het pedagogisch handelen) en feedback hieromtrent ter harte te nemen;
b. de (eigen) onderwijspraktijk verbetert en blijft ontwikkelen;
c. (vak)kennis en -kunde actueel kan houden;

5. aantoonbaar samenwerkt en communiceert met collega's en omgeving, en dus:

a. het pedagogisch handelen kan bespreken met collega's en met anderen die voor de ontwikkeling van de leerling verantwoordelijk zijn;
b. de ontwikkeling van het vak/curriculum in de school kan bespreken met collega's en met anderen die voor de ontwikkeling van de leerling verantwoordelijk zijn.