Appendices: Bachelor's degree programmes in Mathematics and Applied Mathematics

Appendix I Learning outcomes of the degree programme (Article 1.3)

The Bachelor's degree programmes in Mathematics and Applied Mathematics aim to impart knowledge, skills, understanding and an academic attitude in the fields of mathematics and applied mathematics respectively by means of a broadly based curriculum such that Bachelor's graduates are able to work as independent professionals and are also qualified for further training to become academic researchers in these fields.

This aim has been translated into a set of learning outcomes, drawn up in general terms by the Faculty of Mathematics and Natural Sciences of the University of Groningen. First, a number of generic learning outcomes are formulated, which apply to the Bachelor's degree programmes in Astronomy, Physics, Applied Physics, Chemistry, Chemical Engineering, Mathematics and Applied Mathematics, to which specific learning outcomes for each degree programme are subsequently added.

A. Generic learning outcomes – Knowledge

A1. Bachelor's graduates have general knowledge of the foundations and history of mathematics, natural sciences and technology, in particular those of their own discipline.

A2. Bachelor's graduates have mastered the basic concepts of their own discipline (see Appendix I for further specification) to a certain extent and are familiar with the interrelationships of these concepts within their own discipline as well as with other disciplines.

A3. Bachelor's graduates have in-depth knowledge of several current topics within their own discipline.

A4. Bachelor's graduates are familiar with the quantitative character of the fields of mathematics and natural sciences and have an understanding of the methods used in these fields, and particularly within their own discipline, including computer-aided methods.

A5. Bachelor's graduates have sufficient knowledge and understanding of mathematics and natural sciences to successfully complete a follow-up Master's degree programme in their own discipline.

A6. Bachelor's graduates are aware of the societal, ethical and social aspects involved in the fields of mathematics and natural sciences.

B. Generic learning outcomes – Skills

B1 (Research) Bachelor's graduates are able to draw up a research question, design, plan and conduct research and report on it independently with a certain degree of supervision. Bachelor's graduates are able to evaluate the value and limitations of their research and assess its applicability outside their own field.

B2 (Designing and Modelling) Bachelor's graduates are able to translate a problem, in particular a design problem, into a plan of approach and – taking into account the requirements of the client and/or technical preconditions – find a solution.

B3 (Gathering information) Bachelor's graduates are able to gather relevant information using modern means of communication and to critically interpret this information.

B4 (Collaborating) Bachelor's graduates are able to collaborate in teams (including multidisciplinary teams) on technical-scientific problems.

B5 (Communicating) Bachelor's graduates are able to communicate orally and in writing in academic and professional contexts, with both colleagues and others, in Dutch and English. They are familiar with the relevant means of communication.

B6 (Reflecting) Bachelor's graduates are able to assess their own actions and those of others in a natural sciences context, bearing in mind the social/societal and ethical aspects.

B7 (Learning skills) Bachelor's graduates are able to apply learning skills that enable them to pursue a follow-up degree and acquire knowledge in new fields with a high level of autonomy.

B8 Additional subject-specific skills are listed in Appendix II.

Appendix I Degree programme-specific learning outcomes – Basic knowledge

1.1. Bachelor's graduates have mastered the basic concepts and techniques of mathematics, in particular single and multivariable calculus, linear algebra, analysis, ordinary differential equations, probability theory and statistics, and algebra.
1.2. Bachelor's graduates have knowledge of more advanced subjects within the fields of algebra and geometry, analysis and numerical mathematics, as well as dynamical systems and systems theory.
1.3. (Mathematics) Bachelor's graduates have specific knowledge of one of the fields of Pure Mathematics, Physics, Logic, Philosophy, Statistics or Econometrics.
1.4. (Applied Mathematics) Bachelor's graduates have knowledge of more advanced topics in the fields of Computational Science and Numerical Mathematics, and Systems, Control and Optimization.
1.5. Bachelor's graduates have gained knowledge of and experience in the 'heart' of mathematics, i.e. the truth and value of exact mathematical proof.
1.6. Bachelor's graduates have knowledge of mathematical applications in various other fields of study.
1.7. Bachelor's graduates are able to use mathematical software packages in an effective way or, if necessary, develop programs themselves.
1.8. (Minor) Bachelor's graduates have a broad-based knowledge of subjects within their own or a different discipline.

Appendix II Degree programme-specific learning outcomes – Skills

Research

2.1 Bachelor's graduates have an academic attitude, which means they are curious, critical, creative and dare to show initiative.
2.2 Bachelor's graduates are able to formulate relatively simple mathematical questions and problems in an exact way, and if necessary adapt them to make them tractable. Bachelor's graduates are able to articulate assumptions, understand the importance of detailed definitions, and are able to think in an organized way, to apply exact logical arguments when solving problems, and to generalize and abstract.
2.3 Bachelor's graduates are able to analyze and abstract simple problems that are outside the scope of their own study programme and to independently acquire new knowledge to this end.

Designing and modelling

2.4 Bachelor's graduates are able, under supervision and from the perspective of their field of interest, to translate a problem into a relevant mathematical problem definition and to this end formulate and evaluate a solution based on source research.
2.5 Bachelor's graduates are able to formulate concrete problems from application areas as mathematical problems.
2.6 Bachelor's graduates are able to approach mathematical problems on the basis of a certain logical system, and are willing to try out more than one method with a certain degree of determination.
2.7 Bachelor's graduates are aware of the importance of researching specific cases and examples and have the attitude and skills necessary to critically evaluate the solutions found, test them for correctness and interpret them.
2.8 Bachelor's graduates are able, by abstracting and modelling, to delve into the root of a problem and determine whether existing methods can be applied or new methods must be developed.

Appendix II Follow-on Master's degree programmes (Article 1.5)

The Bachelor's degree programme will grant unconditional admission to the following Master's degree programmes at the University of Groningen:

- Mathematics
- Applied Mathematics
- Education and Communication in Mathematics and Natural Sciences (Science Communication programme, language of instruction is Dutch)
- Energy and Environmental Sciences

Appendix III Majors and Minors in the degree programme (Article 2.1.2)

2009-2010 and earlier cohorts: See the appendices to the OER for the starting year of the degree programme.

2010-2011 and later cohorts:
The Bachelor's degree programme in Mathematics has two specializations:

- General Mathematics
- Statistics and Econometrics

The General Mathematics specialization comprises

1) a Mathematics Major (150 ECTS)
2) a Minor (30 ECTS) to be chosen from
    a. University-wide broadening Minors
    b. Faculty-wide deepening Minors
        - Biomedical Technology
        - Biomedical Sciences and Behaviour & Neurosciences
        - Ecology, Evolution and Marine Biology
        - Pharmaceutical Sciences
        - Education
        - Artificial Intelligence and Cognition Science
        - Computing Science
        - Molecular Sciences
    c. Deepening Minors for General Mathematics
        - Mathematics & Physics
        - Mathematics, Logic & Philosophy
        - Mathematics
    d. Optional Minor, based on an individual choice of course units to be approved by the Board of Examiners.

The Statistics and Econometrics specialization comprises

1) a Statistics and Econometrics Major (150 ECTS)
2) a deepening Minor in Statistics and Econometrics (30 ECTS)

The Bachelor's degree programme in Applied Mathematics comprises

1) an Applied Mathematics Major (150 ECTS)
2) a deepening Minor in Applied Mathematics (30 ECTS)

Appendix IV Course units in the propaedeutic phase

- **List of course units; Article 3.1.1**
- **Course units with one or more practicals; Article 3.2**
- **Form of examinations; Article 7.4**

2009-2010 and earlier cohorts: See the appendices to the OER for the starting year of the degree programme.

2010-2011 and later cohorts:
The propaedeutic phase of the Bachelor's degree programme in Mathematics with specializations in General Mathematics (including three structured tracks in the interest fields of 'Mathematics & Physics', 'Mathematics, Logic & Philosophy' and 'Mathematics') and Statistics and Econometrics, and the Bachelor's degree programme in Applied Mathematics comprise a compulsory joint programme as well as two electives that dovetail with the students' degree programme/specialization/interest field.

Bachelor's degree programme in Mathematics, General Mathematics specialization
Bachelor's degree programme in Mathematics, Statistics and Econometrics specialization
Bachelor's degree programme in Applied Mathematics

1-1. Compulsory programme, year 1

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Calculus 1	5		basic skills assessment, written exam	x
	Introduction to Mathematics	5		written exam	
	Elective, period 1a	5	See 1-2		
Ib	Linear Algebra 1	5		practical assessment, written exam	x
	Mechanics and Relativity 1	5		practical assessment, written exam	x
	Elective, period 1b	5	See 1-2		
IIa	Calculus 2	5		written exam	
	Computer-Assisted Problem-Solving	5		computer practicals, report, written exam	x
	Linear Algebra 2	5		written exam	
IIb	Calculus 3	5		written exam	
	Probability Theory	5		written exam	
	Propaedeutic Project	5		research proposal, implementation of project, oral presentation, report	x

1-2 Optional course units

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Physics Laboratory 1*	5	-	performance and report, written exam	x
	Molecules: Structure, Reactivity, and Function	5	-	practical, report, written exam	x
Ib	Operations Research 1#	5	-	computer practicals, assignments, written exam	x
	Introduction to Logic**	5	-	computer practicals, assignments, written exam	x
	Heat and Transport*	5	-	written exam	

Compulsory for the Statistics and Econometrics specialization

* Programme component for the Mathematics & Physics interest field
** Programme component for the Mathematics, Logic & Philosophy interest field. No elective for Applied Mathematics.

Appendix V Course units in the post-propaedeutic phase

- **List of course units; Article 6.1**
- **Course units with one or more practicals; Article 6.2**
- **Compulsory order of examinations; Article 7.2**
- **Form of examinations; Article 7.4**

Students may not start their Bachelor's research project until they have earned at least 150 ECTS from the Bachelor's programme.

Bachelor's degree programme in Mathematics, General Mathematics specialization
Bachelor's degree programme in Mathematics, Statistics and Econometrics specialization

The post-propaedeutic phase of the Bachelor's degree programme in Mathematics with specializations in General Mathematics and Statistics and Econometrics comprises a compulsory joint programme, an optional programme dovetailing with the student's specialization/interest field, and a Minor that also dovetails with the student's specialization/interest field or can be entirely freely chosen. During each period that includes electives, students must choose one of the available electives that dovetails with their specialization/interest field.

2-1 Compulsory programme, year 2

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Analysis	5		oral examination	
	Statistics	5		written exam	
	Specialization course unit, period Ia	5	See 2-2		
Ib	Complex Analysis	5		written exam	
	Ordinary Differential Equations	5		written exam	
	Project Systems Theory	5		presentation, report, written exam	x
IIa	Science and Society	5		assignments, written exam	
	Metric Spaces	5		written exam	
	Specialization course unit, period IIa	5	See 2-2		
IIb	Numerical Mathematics 1	5		assignments, written exam	x
	Group Theory	5		written exam	
	Specialization course unit, period IIb	5	See 2-2		

2-2. Specialization programme, year 2

Due to changes to the curriculum, the elective programme is different from that in the 2011-2012 OER.

2.2.1. General Mathematics specialization

- Mathematics & Physics interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Integrating Project Mathematical Physics	5	-	assignments, presentation, report	x
IIa	Partial Differential Equations	5	-	written exam	
IIb	Electricity and Magnetism I	5	-	written examination, report	x

- Mathematics, Logic & Philosophy interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Project Mathematical Physics #	5	-	assignments, presentation, report	x
	Statistical Reasoning #	5	-	written exam	
IIa	Partial Differential Equations	5	-	written exam	
IIb	Philosophy of Science 1	5	-	written exam	

Choose one of these two

- Mathematics interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Project Mathematical Physics#	5	-	assignments, presentation, report	x
	Statistical Reasoning#	5	-	written exam	
IIa	Partial Differential Equations	5	-	written exam	
IIb	Functional Analysis	5	-	written exam	

Choose one of these two

Statistics and Econometrics specialization

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Statistical Reasoning	5	-	written exam	
IIa	Finance Theory and Modelling#	5	-	written exam	
	Introduction to Mathematical Economics#	5	-	written exam	
IIb	Introduction to Econometrics#	5	-	written exam, assignments	x
	Introduction to Actuarial Science #	5	-	written exam	

Choose one of these two

3-1. Compulsory programme, year 3

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Minor	15			
Ib	Minor	15			
IIa	Analysis on Manifolds	5		written exam	
	Project Dynamical Systems	5		presentation, report, written exam	
	Elective, period IIa	5	See 3-2		
IIb	Bachelor's Project	15		implementation of project, oral presentation, report	x

3-2 Elective programme, year 3

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
IIa	Statistical Modelling#	5		assignments, written exam	
	Mechanics and Relativity 2*	5		written exam	
	Advanced Logic**	5	Introduction to Logic	written exam	
	Algebraic Structures***	5		written exam	

Compulsory for the Statistics and Econometrics specialization

* Programme component for the Mathematics & Physics interest field
** Programme component for the Mathematics, Logic & Philosophy interest field
* Programme component for the Mathematics interest field

3-3 Deepening Minor, Mathematics & Physics interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Measure Theory and Integration	5		written exam	
	Electricity and Magnetism 2	5	Electricity and Magnetism 1	written exam	
	Quantum Physics 1 1	5		written exam	
Ib	Bachelor's Workgroup	5		oral presentation, report	
	Geometry	5		written exam	
	Waves and Optics	5		written examination, report	x

3-4 Deepening Minor, Mathematics, Logic & Philosophy interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Measure Theory and Integration	5		written exam	
	Mathematical Modelling	5		assignments	
	Philosophy of Science 2	5	Philosophy of Science 1	assignments	
Ib	Bachelor's Workgroup	5		oral presentation, report	
	Philosophy of Natural Sciences	5		written exam	
	Chaos Theory	5		presentation, essay	

3-5 Deepening Minor, Mathematics interest field

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Measure Theory and Integration	5		written exam	
	Mathematical Modelling	5		assignments	
	Security and Coding	5		assignments	
Ib	Bachelor Workgroup	5		oral presentation, report	
	Geometry	5		written exam	
	Chaos Theory	5		presentation, essay	

3-6 Deepening Minor, Statistics and Econometrics specialization

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Measure Theory and Integration	5		written exam	
	Mathematical Modelling	5		assignments	
	Stochastic Models	5		written exam	x
Ib	Bachelor's Workgroup	3		oral presentation, report	
	Calculus of Variations and Optimal Control	5		assignments, written exam	
	Dynamic Econometrics#	7		assignments, paper, written exam	
	Risk Insurance#	7		assignments, paper, written exam	

Choose one of these course units

Bachelor's degree programme in Applied Mathematics

The post-propaedeutic phase of the Bachelor's degree programme in Applied Mathematics comprises a compulsory programme and an elective programme (the deepening Minor in Applied Mathematics is integrated into the programme). During each period that includes electives, students must choose one of the available electives.

2-1 Compulsory programme, year 2

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Analysis	5		oral examination	
	Statistics	5		written exam	
	Project Mathematical Physics	5		assignments, presentation, report	x
Ib	Complex Analysis	5		written exam	
	Ordinary Differential Equations	5		written exam	
	Project Systems Theory	5		presentation, report, written exam	
IIa	Science and Society	5		assignments, written exam	
	Metric Spaces	5		written exam	
	Partial Differential Equations	5		written exam	
IIb	Numerical Mathematics 1	5		assignments, written exam	x
	Group Theory	5		written exam	
	Fluid Dynamics	5		oral examination	

3-1 Compulsory programme, year 3

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Mathematical Modelling	5		written exam	
	Computational Methods of Science	5		written exam	
	Elective	5	See 3-2		
Ib	Bachelor's Workgroup	5		oral presentation, report	
	Calculus of Variations and Optimal Control	5		written exam	
	Elective	5	See 3-2	written exam	
IIa	Analysis on Manifolds	5		written exam	
	Project Dynamical Systems	5		presentation, report, written exam	
	Elective	5	See 3-2		
IIb	Bachelor's Project	15		implementation of project, oral presentation, report	

3-2 Elective programme, year 3

Period	Course unit name	ECTS	Entry requirements	Mode of assessment	Practical
Ia	Control Engineering	5		written examination, report	x
	Imperative Programming	5		assignments, written exam	x
Ib	Geometry	5		written exam	
	Chaos Theory	5		presentation, essay	
IIa	Signals and System Theory	5		written exam	
	Numerical Mathematics 2	5	Numerical Mathematics 1	assignments, written exam	x