About this document

Goal
This document was written to assist VU students in choosing courses within the two mathematical master programs and their tracks:

- **Mathematics**, consisting of six tracks:
  - Algebra and Geometry
  - Analysis and Dynamical Systems
  - Stochastics
  - Biomedical Mathematics
  - Education
  - Teachers
- **Stochastics and Financial Mathematics**

This manual contains information on the overall structure of the Master programs, and lists courses offered in 2019/20 per track, indicating both their level and relevance. Also, several “suggested lines” are given. These are clusters of related courses that offer the possibility of going in depth into several specialisations.

We recommend that you discuss your program with the coordinator of your master program (Corrie Quant for Mathematics, Wouter Kager for SFM) as early as possible.

Other sources of information
Detailed course descriptions can be found in the online VU Mathematics, VU SFM study guides, and on the Mastermath website.

Non-standard programs
If you want to follow a non-standard program (e.g. a major/minor, a double master program, a free program, interdisciplinary program, or if you simply want to include certain courses that are not listed in the program below), then in most cases you will need to have your proposed program approved by the Examination Board. Contact the coordinator of the master program as soon as possible.

Legal disclaimer
No rights can be derived from this document, the only legally binding source regarding your master degree is the *Teaching and Examination Regulations* (commonly known by its Dutch abbreviation OER). You can find this on the webpages of the faculty. Please make sure to request approval of your academic program via VUNET once you know what your complete program will be (usually during the first semester of the second year). Approval for courses which are not mentioned in the list in this manual for your track can also be requested via VUNET.
Mathematics: Algebra and Geometry Track

Program outline

• **6EC**: Master Seminar in Algebra, Geometry and Mathematical Physics (year 1)
• **3EC**: Scientific Writing in English (year 1)
• **36EC**: Master Project Mathematics (year 2)
• **60EC**: Mathematics courses, consisting of
  – At least three courses out of the following six
    * Algebraic Geometry 1
    * Algebraic Topology 1
    * Lie Groups
    * Lie Algebras
    * Quivers
    * Riemann Surfaces
  – At least two Algebra and Geometry courses out of
    * Algebraic Geometry 2
    * Algebraic Topology 2
    * Advanced Algebraic Geometry
    * Modular Forms
    * Seminar Algebra
    * Topology in Physics
  – Remainder (about 30EC) mathematics courses (all tracks)
• **15EC**: Free (must be master level; can be math, literature, …)

Fall 2019

Master Seminar
• Master Seminar in Algebra, Geometry and Mathematical Physics (@UvA)

Suggested basic courses
• Algebraic Geometry 1 (Mastermath)
• Algebraic Number Theory (Mastermath)
• Algebraic Topology 1 (Mastermath)
• Commutative Algebra (Mastermath)
• Cryptology (Mastermath)
• Lie Groups (Mastermath)
• Seminar Algebra (VU)
• Quivers (UvA)

Other suggested courses (advanced)
• Advanced Algebraic Geometry (Mastermath)
Mathematics: Algebra and Geometry Track

- Differential Geometry (Mastermath)
- Diophantine Approximation (Mastermath)
- Category Theory and Topos Theory (Mastermath)
- Blowing Ups and Deformations: an Introduction to the Theory of Singularities (UvA)
- Advanced Combinatorics: zeros of graphs polynomials, Markov chains and algorithms (UvA)
- Poisson Geometry (Mastermath)

Related courses
- Functional Analysis (Mastermath)

Spring 2020

Master Seminar
- Master Seminar in Algebra, Geometry and Mathematical Physics (@UvA)

Suggested basic courses
- Algebraic Methods in Combinatorics (Mastermath)
- Coding and Cryptography (VU)
- Lie Algebras (Mastermath)
- Operator Algebras (Mastermath)
- Riemann Surfaces (Mastermath)

Other suggested courses (advanced)
- Algebraic Geometry 2 (Mastermath)
- Algebraic Topology 2 (Mastermath)
- Topology in Physics (UvA)
- Topology of Algebraic Varieties (UvA)
- Modular Forms (Mastermath)
- Selected Areas in Cryptology (Mastermath)
- Symplectic Geometry (Mastermath)
- Quantum Computing (Mastermath)
- Quantum Information Theory (Mastermath)

Related courses
- Topological Data Analysis (Mastermath)

Suggested lines

Algebraic Geometry
- Basic: Algebraic Geometry 1, Commutative Algebra
- Advanced: Algebraic Geometry 2, Advanced Algebraic Geometry, Seminar Algebra
- Related: Algebraic Topology 1, Algebraic Topology 2, Riemann Surfaces
Mathematics: Algebra and Geometry Track

**Differential Geometry**
- Basic: Lie Groups, Lie Algebras, Riemann Surfaces
- Advanced: Differential Geometry, Poisson Geometry, Symplectic Geometry
- Related: Algebraic Topology 1, Topology in Physics, Functional Analysis

**Mathematical Physics**
- Basic: Algebraic Topology 1, Lie Groups, Lie Algebras
- Advanced: Differential Geometry, Topology in Physics, Symplectic Geometry
- Related: Algebraic Geometry 1, Functional Analysis, Operator Algebras

**Number Theory**
- Basic: Algebraic Number Theory, Diophantine Approximation, Modular Forms, Lie Groups, Lie Algebras
- Advanced: Algebraic Geometry 2,
- Related: Algebraic Geometry 1, Commutative Algebra, Riemann Surfaces

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**Research staff in Algebra and Geometry**

**UvA**

**VU**
Magnus Botnan, Sander Dahmen, Oliver Fabert, Rob de Jeu, Federica Pasquotto, Jan Sanders, Rob van der Vorst.
Mathematics: Analysis and Dynamical Systems Track

Program outline

- **6EC**: Master Seminar in Analysis and Dynamical Systems (year 1)
- **3EC**: Scientific Writing in English (year 1)
- **36EC**: Master Project Mathematics (year 2)
- **60EC**: Mathematics courses, consisting of
  - At least three courses out of
    * Functional Analysis
    * Partial Differential Equations
    * Dynamical Systems
    * Numerical Linear Algebra
  - At least two Analysis and Dynamical Systems courses out of
    * Calculus of Variations
    * Inverse Problems in Imaging
    * Numerical Methods for stationary PDEs
    * Symplectic Geometry
  - Remainder (about 30EC): mathematical courses (all tracks)
- **15EC**: Free (must be master level; can be math, literature, . . .)

Fall 2019

Master Seminar
- Master Seminar in Analysis and Dynamical Systems (@UvA)

Suggested basic courses
- Continuous Optimization (Mastermath)
- Dynamical Systems (Mastermath)
- Functional Analysis (Mastermath)
- Mathematical Biology (Mastermath)
- Parallel Algorithms (Mastermath)
- Partial Differential Equations (Mastermath)
- Numerical Linear Algebra (Mastermath)

Other suggested courses (advanced)
- Numerical Methods for stationary PDEs (UvA)
- Advanced Topics in Stochastic Analysis (UvA)
- Differential Geometry (Mastermath)
- Poisson Geometry (Mastermath)
Related courses
- Mathematical Biology (Not in 18/19)
- Measure Theoretic Probability (Mastermath)
- Lie Groups (Mastermath)

Spring 2020

Master Seminar
- Master Seminar in Analysis and Dynamical Systems (@VU)

Suggested basic courses
- Applied Finite Elements (Mastermath)
- Calculus of Variations (Mastermath)
- Introduction to Numerical Bifurcation Analysis of ODEs and Maps (Mastermath)
- Riemann Surfaces (Mastermath)
- Complex Dynamical Systems (UvA)

Other suggested courses (advanced)
- Inverse Problems in Imaging (Mastermath)
- Stochastic Integration (UvA)

Related courses
- Lie Algebras (Mastermath)
- Operator Algebras (Mastermath)
- Symplectic Geometry (Mastermath)

Suggested lines

Dynamical systems
- Basic: Dynamical Systems, Partial Differential Equations, Introduction to Numerical Bifurcation Analysis of ODEs and Maps, Complex Dynamical Systems
- Advanced: Numerical Methods for stationary PDEs, Calculus of Variations
- Related: Functional Analysis, Inverse Problems in Imaging, Mathematical Biology, Stochastic Integration

Numerical Analysis
- Advanced: Inverse Problems in Imaging, Numerical Methods for stationary PDEs
- Related: Functional Analysis, Parallel Algorithms
Research staff in Analysis and Dynamical Systems

**UvA**
Jan Brandts, Daan Crommelin, Ale Jan Homburg, Han Peters, Rob Stevenson, Chris Stolk, Jan Wiegerinck.

**VU**
Jan Bouwe van den Berg, Magnus Botnan, Frank Bruggeman, Oliver Fabert, Ale Jan Homburg, Joost Hulshof, Rien Kaashoek, Federica Pasquotto, Bob Planqué, André Ran, Bob Rink, Jan Sanders, Rob van der Vorst.
Mathematics: Stochastics Track

Program outline

- **6EC**: Master Seminar in Stochastics (two semesters, year 1)
- **3EC**: Scientific Writing in English (year 1)
- **36EC**: Master Project Mathematics (year 2)
- **60EC**: Mathematics courses, consisting of
  - Compulsory courses:
    * Asymptotic Statistics
    * Measure Theoretic Probability
    * Stochastic Processes
  - At least 2 advanced Stochastics courses
  - Remainder (about 30C): mathematics courses (all tracks)
- **15EC**: Free (must be master courses; can be math, literature, . . .

Fall 2019

Master Seminar
- **Master Seminar in Stochastics** (@UvA)

Suggested basic courses
- Advanced Machine Learning (VU)
- Applied Stochastic Modelling (VU)
- Asymptotic Statistics (Mastermath)
- Forensic Probability and Statistics (Mastermath)
- Functional Analysis (Mastermath)
- Machine Learning Theory (Mastermath)
- Measure Theoretic Probability (Mastermath)
- Partial Differential Equations (Mastermath)
- Simulation Methods in Statistics (UvA)
- Statistical Models (VU)
- Stochastic Networks (UvA)
- Stochastic Optimization (VU)
- Stochastics Processes for Finance (VU)
- Stochastic Simulation (UvA)
- Uncertainty Quantification and Data Assimilation (UvA)

Advanced courses
- Advanced Topics in Stochastic Analysis (UvA)
- Interest Rate Models (UvA)
- Portfolio Theory (UvA)
Random Walks (Mastermath)

Related courses
- Mathematical Biology (Mastermath)

Spring 2020

Master Seminar
- Master Seminar in Stochastics (@VU)

Suggested basic courses
- Queueing Theory (Mastermath)
- Scheduling (Mastermath)
- Stochastic Differential Equations (Mastermath)
- Stochastic Integration (UvA)
- Stochastic Processes (Mastermath)

Advanced courses
- Bayesian Statistics (Mastermath, niet in 19/20)
- Complex Networks (Mastermath)
- Data-Driven Decision Making in Operations Research (UvA)
- Queues and Levy Fluctuation Theory (UvA)
- Percolation: from Introduction to Frontiers of Current Research (Mastermath)
- Statistics for Stochastic Processes (Mastermath)
- Statistical Theory for High- and Infinite-Dimensional Models (Mastermath)
- Statistics for High-dimensional Data (VU)

Related courses
- Optimization of Business Processes (VU)
- Statistical Theory for High- and Infinite-Dimensional Models (not every year)

Suggested lines

Probability
- Basic: Asymptotic Statistics, Forensic Probability and Statistics, Measure Theoretic Probability
- Advanced: Percolation: from Introduction to Frontiers of Current Research, Random Walks, Complex Networks
- Related: Functional Analysis, Stochastic Integration
**Mathematics: Stochastics Track**

**Statistics**
- **Basic:** Applied Statistics, Asymptotic Statistics, Measure Theoretic Probability, Statistical Models,
- **Advanced:** Statistical Theory for High- and Infinite-Dimensional Models, Statistics for High-dimensional Data, Statistics for Networks (not in 19/20), Bayesian Statistics (not in 19/20)

**Financial Mathematics**
- **Basic:** Measure Theoretic Probability, Stochastics Processes for Finance
- **Advanced:** Interest Rate Models, Portfolio Theory
- **Related:** Functional Analysis, Partial Differential Equations

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**Research staff in Stochastics**

**UvA**
Arnoud den Boer, Sonja Cox, Daan Crommelin, Jan-Pieter Dorsman, Bert van Es, Asma Khedher, Chris Klaassen, Bas Kleijn, Michel Mandjes, Sindo Núñez Queija, Marjan Sjerps, Peter Spreij, Erik Winands.

**VU**
René Bekker, Eduard Belitser, Rob van den Berg, Sandjai Bhulai, Federico Camia, Dennis Dobler, Elenna Dugundji, Rikkert Hindriks, Mathisca de Gunst, Wouter Kager, Ger Koole, Ronald Meester, Rob van der Mei, Klaas Slooten, Wessel van Wieringen, Harry van Zanten.
Mathematics: Biomedical Mathematics Track

Program outline

- **6EC**: Master Seminar in Analysis and Dynamical Systems or Master Seminar in Stochastics (two semesters, year 1)
- **3EC**: Scientific Writing in English (year 1)
- **36EC**: Master Project Mathematics (year 2)
- **30EC**: Minor Biomedical Mathematics
- **36EC**: Mathematics courses, consisting of
  - Compulsory courses:
    - Statistical Models
    - Dynamical Systems
    - Mathematical Biology
  - Remainder (14EC): mathematics courses (all tracks)
- **9EC**: Free (must be master courses; can be math, literature, . . . )

Minor Biomedical Mathematics
For this minor we suggest 5 life science courses (see below). The minor may also include an 18EC applied project for students who already followed the VU biomedical mathematics program in the bachelor.
The minor of the Master may include at most 18EC of the bachelor courses currently in the “Biomedische Wiskunde” variant of the bachelor at the VU, for students who did not yet follow those courses. Specifically: Biochemie, Medische Fysiologie, Principles of Systems Biology, Introductie Medische Beeldbewerking.

Fall 2019

Master Seminar
- Master Seminar in Analysis and Dynamical Systems or Master Seminar in Stochastics

Suggested Mathematics courses
- Asymptotic Statistics (Mastermath)
- Complex Networks (Mastermath)
- Dynamical Systems (Mastermath)
- Functional Analysis (Mastermath)
- Mathematical Biology (Mastermath)
- Introduction to Numerical Bifurcation Analysis of ODEs and maps (Mastermath, not every year)
- Partial Differential Equations (Mastermath)
- Statistical Models (VU)
• Statistics for Networks (VU, not in 19/20)

**Suggested life science courses in the Minor Biomedical Mathematics**
• From Molecule to Mind (VU, period 1)
• Algorithms in Sequence Analysis (VU, period 2)
• Mechanics and Thermodynamics in the Cell (VU, period 2)

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**Spring 2020**

**Master Seminar**
• Master Seminar in Analysis and Dynamical Systems (@VU) or Master Seminar in Stochastics (@VU)

**Suggested Mathematics courses**
• Complex Networks (Mastermath)
• Inverse Problems in Imaging (Mastermath)
• Statistics for High-dimensional Data (VU)
• Stochastic Processes (Mastermath)

**Suggested life science courses in the Minor Biomedical Mathematics**
• Basic Models of Biological Networks (VU, period 4)
• Advanced Modeling in Systems Biology (VU, period 6)

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**Research staff in Mathematical Biology**

**VU**
Jan Bouwe van den Berg, Frank Bruggeman, Mathisca de Gunst, Rikkert Hindriks, Joost Hulshof, Bob Planqué, Mark van de Wiel, Wessel van Wieringen.
Mathematics: Education Track

Program outline

- **24EC**: Master Project Mathematics (T, E track) (year 1)
- **24EC**: Mathematics courses, from the MasterMath and local program. This excludes the MasterMath teacher courses.
- **12EC**: Free (must be master courses, but may include the MasterMath teacher courses; can be math, literature, ...)
- **60EC**: Teaching qualification (including internship)

Alternative program for students with an Education Minor (30EC obtained earlier in the Bachelor)

- **24EC**: Master Project Mathematics (T, E track) (year 2)
- **33EC**: Teaching qualification (reduced: didaktiek, praktijk en onderzoek)
- **24EC**: Mathematics courses from the MasterMath and local master program. This excludes the MasterMath teacher courses.
- **12EC**: Free (must be master courses, but may include the MasterMath teacher courses; can be math, literature, ...)
Mathematics: Teachers Track

This track has a special entry requirement: HBO students from the “lerarenopleiding wiskunde” with a “tweedegraadsbevoegdheid” can enter this track after having followed a premaster program (consisting of a specific selection of 30EC of first year bachelor courses). In the Teacher track, they follow a lot of mandatory courses (42EC) and must reach the exit level of the Education track.

Program outline

- **24EC**: Master Project Mathematics (T, E track) (year 2)
- **30EC**: Teaching qualification (reduced, including internship)
- **66EC**: Mathematics courses, consisting of
  - Compulsory courses:
    - Complexe Analyse
    - Dynamische Systemen
    - Measure Theory
    - Numerical Methods
    - Statistical Data Analysis
    - Statistics
  - Remainder (30C): mathematics courses from the MasterMath and local master program. This excludes the MasterMath teacher courses.
Stochastics and Financial Mathematics

Program outline

- **3EC**: Master Seminar Stochastics and Financial Mathematics (year 1)
- **3EC**: Scientific Writing in English (year 1)
- **36EC**: Master Project SFM (year 2)
- **63EC**: Designated SFM courses from the list below, consisting of
  - Measure Theoretic Probability (Mastermath)
  - either at least 2 Financial Mathematics courses, out of
    - Computational Finance (UvA master Computational Science)
    - Interest Rate Models (UvA)
    - Portfolio Theory (UvA)
    - Stochastics Processes for Finance (VU)
  - or at least 2 Data Science courses, out of
    - Advanced Machine Learning (VU)
    - Stochastic Optimization (VU)
    - Statistical Models (VU)
    - Planning and Reinforcement Learning (VU)
  - at least 2 advanced SFM courses
- **12EC**: Free (must be master courses; can be a designated SFM course, Math, . . .)

Fall 2019

Master Seminar

- Master Seminar Stochastics and Financial Mathematics (UvA/VU)

Designated SFM courses

- Advanced Machine Learning (VU)
- Applied Stochastic Modelling (VU)
- Asymptotic Statistics (Mastermath)
- Forensic Probability and Statistics (Mastermath)
- Functional Analysis (Mastermath)
- Heuristic Methods in Operations Research (Mastermath)
- Interest Rate Models (UvA)
- Machine Learning Theory (Mastermath)
- Measure Theoretic Probability (Mastermath)
- Partial Differential Equations (Mastermath)
- Planning and Reinforcement Learning (VU)
- Portfolio Theory (UvA)
- Probabilistic and Extremal Combinatorics (Mastermath)
- Random Walks (Mastermath)
• Simulation Methods in Statistics (UvA)
• Statistical Models (VU)
• Stochastic Optimization (VU)
• Stochastic Networks (UvA)
• Stochastics Processes for Finance (VU)
• Stochastic Simulation (UvA)

Advanced SFM courses
• Advanced Machine Learning (VU)
• Advanced Topics in Stochastic Analysis (UvA)
• Interest Rate Models (UvA)
• Portfolio Theory (UvA)
• Statistics for Networks (VU, not in 19/20)
• Stochastic Networks (UvA)
• Stochastic Simulation (UvA)

Spring 2020

Designated SFM courses
• Applied Analysis: Financial Mathematics (VU)
• Applied Statistics (Mastermath)
• Bayesian Statistics (Mastermath)
• Computational Finance (UvA master Computational Science)
• Data-drive Decision Making in Operations Research (UvA)
• Entrepreneurship in Data Science and Analytics (VU)
• Optimization of Business Processes (VU)
• Percolation: from Introduction to Frontiers of Current Research (Mastermath)
• Performance of Networked Systems (VU)
• Queuing Theory (Mastermath)
• Queues and Levy Fluctuation Theory (UvA)
• Stochastic Differential Equations (Mastermath)
• Statistics for High-dimensional Data (VU)
• Statistics for Stochastic Processes (Mastermath)
• Statistics for Networks (VU)
• Stochastic Integration (UvA)
• Stochastic Processes (Mastermath)

Advanced SFM courses
• Data-drive Decision Making in Operations Research (UvA)
• Percolation: from Introduction to Frontiers of Current Research (Mastermath, not in 2018/2019)
• Queues and Levy Fluctuation Theory (UvA)
• Statistics for High-dimensional Data (VU)
• Statistics for Networks (VU)
• Statistics for Stochastic Processes (Mastermath)
Research staff in SFM

UvA
Arnoud den Boer, Sonja Cox, Jan-Pieter Dorsman, Bert van Es, Asma Khedher, Chris Klaassen, Bas Kleijn, Michel Mandjes, Sindo Núñez Queija, Marjan Sjerps, Peter Spreij, Robin de Vilder, Erik Winands.

VU
René Bekker, Eduard Belitser, Rob van den Berg, Sandjai Bhulai, Dennis Dobler, Elenna Dugundji, Rikkert Hindriks, Mathisca de Gunst, Wouter Kager, Ger Koole, Ronald Meester, Rob van der Mei, Harry van Zanten.
Final remarks

Free Masters

As prescribed in part A of the OER, students may apply to the Board of Examiners to do a “free master”, in which they are not bound to a track. This is not generally advised, unless there is a focus on some research area not represented in the tracks, such as mathematical logic or discrete mathematics. The criteria roughly are:

- **6EC**: One of the three Master Seminars
- **3EC**: Scientific Writing in English
- **36EC**: Master Project Mathematics
- **36EC**: A coherent selection of Master courses in Mathematics or logic, offered in Amsterdam or in Mastermath. At least two of these should be advanced Master courses. The meaning of “coherent” is to be decided by the Board of Examiners.
- **24EC**: Other mathematics courses offered locally and in MasterMath.
- **15EC**: Free (must be master level; can be math, literature, . . .)

Interdisciplinary Masters

The Biomedical Mathematics track is an example of an interdisciplinary track. If a student would like to combine mathematics with another discipline, then the Board of Examiners can approve such a program. The criteria roughly are:

- **6EC**: One of the three Master Seminars
- **3EC**: Scientific Writing in English
- **36EC**: Master Project Mathematics
- **30EC**: A Minor, consisting of a coherent selection of Master courses in a field that is (loosely) related to Mathematics. The meaning of “coherent” is to be decided the Board of Examiners.
- **36EC**: Mathematics courses offered locally or in MasterMath. At least two of these should be advanced Master courses.
- **9EC**: Free (must be master level; can be math, literature, . . .)

Other courses

Several courses that may be followed in the Master Mathematics or as elective courses in the Master SFM, do not fall explicitly under a track and hence were not mentioned in this document. For more details we refer to the online UvA and VU study guides, and the Mastermath website.