UNIVERSITY OF GOTHENBURG

FACULTY OF SCIENCE

Mathematical Sciences, Master's Programme, 120 credits

Matematiska vetenskaper, masterprogram, 120 högskolepoäng

Programme code: N2MAT

Second cycle / Avancerad nivå

1. Confirmation

This programme syllabus was confirmed by the Faculty Board of Science on 03-09-2019 (GU 2019/2060) to be valid from 03-09-2019, Autumn semester 2019.

Responsible Department/equivalent: Department of Mathematical Sciences

2. Purpose

The Master's program in Mathematical Sciences offers a wide range of courses for further studies within mathematics and mathematical statistics. The program provide a further insight into the applications and areas of mathematics and mathematical statistics and its great importance within many various sciences. The program prepare professional mathematicians and statisticians both for employment within business and the public sector, for postgraduate education and for research at universities.

3. Entry requirements

In addition to a bachelor's degree, knowledge equivalent to 75 higher education credits is required in mathematics and mathematical statistics, of which at least 15 higher education credits must be at an advanced bachelor's level.

In addition, English 6 / English B or equivalent results are required on a recognized international test such as TOEFL or IELTS, or a degree from an English-speaking university.

There are special prerequisites for the courses which are stated in the respective syllabus. Depending on the student's background, it may be necessary to supplement with bachelor level courses in order to be able to follow the courses within a certain specialization.

To follow the specialization Mathematical statistics, knowledge equivalent to the courses MSG110 Probability theory, MSG800 Basic stochastic processes, MSG200 Statistical inference, MSG400 Statistical data processing and simulation, and MSG500 Linear statistical models are

recommended.

It is possible within the program to supplement with a maximum of 30 higher education credits of bachelor level courses that may be missing.

4. Higher education qualification and main field of study

This programme leads to a Degree of Master of Science (120 credits) with a major in Mathematical Statistics (Filosofie masterexamen med huvudområdet Matematisk statistik). This programme leads to a Degree of Master of Science (120 credits) with a major in Mathematics (Filosofie masterexamen med huvudområdet Matematik).

The specializations *Mathematics* and *Applied mathematics* leads to a Degree of Master of Science with a major in Mathematics.

The specializations *Mathematical Statistics* and *Statistical Learning and AI* leads to a Degree of Master of Science with a major in Mathematical Statistics.

The specialization *Financial mathematics* leads either to a Degree of Master of Science with a major in Mathematics or to a Degree of Master of Science with a major in Mathematical Statistics, depending on the courses chosen and the degree project.

5. Outcomes

Second-cycle study programmes shall involve the acquisition of specialist knowledge, competence and skills in relation to first-cycle courses and study programmes, and in addition to the requirements for first-cycle courses and study programmes shall:

- further develop the ability of students to integrate and make autonomous use of their knowledge,
- develop the students' ability to deal with complex phenomena, issues and situations, and
- develop the students' potential for professional activities that demand considerable autonomy, or for research and development work.

General outcomes for Degree of Master (120 credits)

Knowledge and understanding

For a Degree of Master (120 credits) the student shall

- demonstrate knowledge and understanding in the main field of study, including both broad knowledge of the field and a considerable degree of specialized knowledge in certain areas of the field as well as insight into current research and development work, and
- demonstrate specialized methodological knowledge in the main field of study.

Competence and skills

For a Degree of Master (120 credits) the student shall

- demonstrate the ability to critically and systematically integrate knowledge and analyse, assess and deal with complex phenomena, issues and situations even with limited information

- demonstrate the ability to identify and formulate issues critically, autonomously and creatively as well as to plan and, using appropriate methods, undertake advanced tasks within predetermined time frames and so contribute to the formation of knowledge as well as the ability to evaluate this work
- demonstrate the ability in speech and writing both nationally and internationally to clearly report and discuss his or her conclusions and the knowledge and arguments on which they are based in dialogue with different audiences, and
- demonstrate the skills required for participation in research and development work or autonomous employment in some other qualified capacity.

Judgement and approach

For a Degree of Master (120 credits) the student shall

- demonstrate the ability to make assessments in the main field of study informed by relevant disciplinary, social and ethical issues and also to demonstrate awareness of ethical aspects of research and development work
- demonstrate insight into the possibilities and limitations of research, its role in society and the responsibility of the individual for how it is used, and
- demonstrate the ability to identify the personal need for further knowledge and take responsibility for his or her ongoing learning.

Local outcomes

Specific learning outcomes for each specialization

Mathematics
For a Degree of Master (120 credits) the student shall also:

- be able to independently handle various proof ideas within a central area of mathematics
- be able to work independently with development of methods and theories within the area of mathematics
- be well prepared for postgraduate studies in mathematics

Applied Mathematics
For a Degree of Master (120 credits) the student shall also:

- have good ability to construct mathematical models for realistic problems and to analyze these numerically and analytically
- be familiar with mathematical software and the role of the computer in various mathematical applications
- be well prepared for work within business and industry which requires advanced mathematical methods

Financial Mathematics
For a Degree of Master (120 credits) the student shall also:

- understand and be able to independently formulate and analyze financial mathematical models
- have the ability to solve financial problems that require advanced mathematical knowledge

- be able to follow developments in financial mathematics
- be well prepared for work within the financial sector

Mathematical statistics
For a Degree of Master (120 credits) the student shall also:

- be able to understand and independently formulate and analyze statistical models
- be able to solve problems and use advanced methods applied in probability theory, stochastic processes and statistics
- be well acquainted with the computer's role in applied statistics and simulation
- be well prepared for postgraduate education within mathematical statistics and / or work in the industry that require advanced statistical methods

Statistical learning and AI
For a Degree of Master (120 credits) the student shall also:

- have the ability to handle large amounts of data and be able to select and apply advanced statistical methods to extract information from them
- be able to follow the development in statistical learning and AI
- be familiar with, able to manage and also further develop software used in statistical learning and AI
- be well prepared for work within AI

6. Content and structure

Within the program there is a wide range of courses at the advanced level to choose from, but there is also the possibility to supplement with courses at the undergraduate level (maximum 30 credits) and / or within any other subject. One can also include postgraduate courses in the education.

The program has five specializations:

- Mathematics
- Applied mathematics
- Financial mathematics
- Mathematical statistics
- Statistical learning and AI

The student will in collaboration with the student counselor do an individual study plan to ensure the requirements for at least one of the specializations are met at the end of the studies. Regardless of the specialization, the course MVA200 Perspectives on Mathematics (7.5 credits) is mandatory and should be taken during the first semester of the program. Below are the specific requirements within each specialization. All courses, except the degree project, are at 7.5 credits.

The specialization Mathematics

For a degree in Mathematics at least two of the following courses are taken:

- MMA110 Integration Theory

- MMA120 Functional analysis
- MMA130 Distribution theory
- MMA140 Spectral theory and operator algebra
- MMA210 Advanced calculus
- MMA430 Partial differential equations II
- Analysis in several complex variables

and at least two of the following specialization courses:

- MMA100 Topology
- MMA201 Representation theory
- MMA310 Galois theory
- MMA320 Introduction to algebraic geometry
- MMA330 Commutative algebra
- MMA340 Analytic number theory
- MMA350 Algebraic number theory

and an independent degree project within the course MMA910 Thesis in Mathematics for the two-year Masters Program in Mathematical Sciences (30 credits).

Specialization in Applied Mathematics

For a degree in Applied mathematics at least four of the following courses are taken:

- MMA400 Applied functional analysis
- MMA410 Fourier and wavelet analysis
- MMA430 Partial differential equations II
- MMA500 Project course in partial differential equations
- MMA511 Large-scale optimization
- MMA520 Project course in mathematical modeling
- MMA600 Numerical linear algebra
- MMA620 High performance computing
- MMA630 Computational methods for stochastic differential equations

and an independent degree project within the course MMA920 Thesis in Mathematics for the two-year Masters Program in Mathematical Sciences, specialization Applied Mathematics (30 credits).

The specialization Financial mathematics

This specialization is given in collaboration with the School of Business, Economics and Law at the University of Gothenburg. Courses with the course code GMxxxx or HNFxxx are provided by the School of Business, Economics and Law.

For a degree in Financial mathematics the three following compulsory specialization courses are taken:

- MMG810 Options and mathematics
- GM0701 Advanced microeconomic theory
- HNF635 (NEG300) Portfolio investment

and at least three of the following specialization courses:

- MMA110 Integration theory
- MMA630 Computational methods for stochastic differential equations
- MMA711 Financial derivatives and partial differential equations
- MSA101 Computational methods for Bayesian statistics
- MSA220 Statistical learning for big data
- MSA350 Stochastic analysis
- MSA400 Financial risk
- MSA410 Financial time series

and at least two of the following courses:

- GM1002 Financial institutions and markets
- GM0704 Advanced macroeconomic theory
- GM1015 Advanced corporate finance
- GM1014 Applied portfolio management

and an independent degree project within one of the courses:

- MMA930 Thesis in Mathematics for the two-year Masters Program in Mathematical Sciences, specialization Financial mathematics (30 credits), or
- MSA930 Thesis in Mathematical Statistics for the two-year Masters Program in Mathematical Sciences, specialization Financial mathematics (30 credits), depending on whether the student intend to graduate in mathematics or mathematical statistics.

For a degree in mathematics at least one of the following courses are taken:

- MMA110 Integration Theory
- MMA630 Computational methods for stochastic differential equations
- MMA711 Financial derivatives and partial differential equations

The specialization Mathematical statistics

For a degree in Mathematical statistics, courses in mathematical statistics at advanced level of at least 30 credits has to be included. The mathematics course MMA110 Integration theory may be included in these 30 credits. The courses can be partially selected freely, but one must read the mandatory specialization course MSA150 Foundations of probability theory and at least one of the following three specialization courses:

- MSA101 Computational methods for Bayesian statistics
- MSA220 Statistical learning for big data
- MSF100 Statistical inference principles

and an independent degree project within the course MSA910 Thesis in Mathematical Statistics for the two-year Masters Program in Mathematical Sciences (30 credits).

The specialization Statistical learning and AI

For a degree in Statistical learning and AI following three compulsory specialization courses are taken:

- MSA101 Computational methods for Bayesian statistics
- MSA220 Statistical learning for big data
- MMG621 Non-linear optimization

and at least two of the following specialization courses:

- MSA150 Foundations of probability theory
- MSA251 Experimental design and sampling
- MSA301 Spatial statistics and image analysis
- MSA410 Financial time series
- MSA520 Project course in statistical modeling
- MSF100 Statistical inference principles
- MSF200 Stochastic processes

and at least three of the following specialization courses:

- DIT381 Algorithms for machine learning and inference
- DIT411 Introduction to Artificial Intelligence
- DIT602 Algorithms
- DIT621 Databases
- DIT741 Computational methods in bioinformatics
- DIT866 Applied machine learning
- Design of AI system
- Natural language processing
- FIM720 Neural Networks

and an independent degree project within the course MSA940 Thesis in Mathematical Statistics for the two-year Masters Program in Mathematical Sciences, specialization Statistical learning and AI (30 credits).

7. Guaranteed admission

Students who have been admitted to the program have guaranteed admittance for all courses within one of the program's specializations. The number of places on the specializations Financial mathematics and Statistical learning and AI may be limited on courses given by institutions other than Mathematical sciences.

8. Transitional regulations

None.

9. Other information

Evaluation takes place separately in each course within the program. The program as a whole is monitored continuously by the program committee, including through an annual evaluation meeting.

The study programme will be followed up and evaluated in accordance with the applicable *Policy för kvalitetssäkring och kvalitetsutveckling av utbildning vid Göteborgs universitet* (Policy

for the Quality assurance and Quality Development of Education at the University of Gothenburg).