Programme syllabus

Master's Programme, Applied and Computational Mathematics, 120 credits
Masterprogram, tillämpad matematik och beräkningsmatematik
120.0 credits

Valid for students admitted to the education from autumn 18 (HT - Autumn term; VT - Spring term).

This is a translation of the Swedish, legally binding, programme syllabus.

Programme objectives

The main objective of this programme is to produce skilled applied mathematicians, well prepared for advanced industrial positions or continued graduate studies

Knowledge and understanding

A Master of Science in Applied and Computational Mathematics will:

- have a broad knowledge in applied mathematics as well as a significantly deepened knowledge within the chosen area of specialization, including techniques of mathematical modelling, analysis of mathematical models, and simulation,

- be able to, in an independent manner, apply mathematical theories, methods and models,

- be able to formulate and approach new problem settings in a scientific manner, by having a creative, critical and systematic attitude towards applied mathematics.

Skills and abilities

A Master of Science in Applied and Computational Mathematics will be able to:

- formulate mathematical models, choose suitable methods to investigate those models including the efficient use of computer tools,

- analyze different mathematical models within science and technology and work creatively, systematically and critically,
• work out solution strategies to important classes of mathematical problems, knowing the capabilities and limitations of different methods and tools,

• work efficiently in a teamwork environment,

• communicate results and conclusions in a competent and intelligible manner, both orally and in writing, with management, experts, and society at large,

• follow and participate in research and development related to the chosen specialization.

**Ability to make judgements and adopt a standpoint**

A Master of Science in Applied and Computational Mathematics will be able to:

• critically judge the validity and limitations of results obtained from different types of mathematical models,

• identify the need for further knowledge in the field and take initiatives to keep the personal knowledge up to date.

**Extent and content of the programme**

Applied and Computational Mathematics is a two-year (120 university credits) Master’s program on the advanced level (second cycle). The instruction language is entirely English. The program consists of a basic curriculum followed by three tracks: (i) computational mathematics, (ii) optimization and systems theory, (iii) statistical learning and data analytics, and (iv) financial mathematics. The courses in the basic curriculum are compulsory and worth 30 university credits. To obtain sufficient depth in a track, a student is required to complete courses worth approximately 30 university credits among the profile courses for the track in question.

**Eligibility and selection**

**General eligibility requirements**

A completed Bachelor’s degree (BSc, BEng of corresponding) comprising 180 university credits from a university approved by the Swedish authorities or accredited of an authorized organization. Working knowledge in written and spoken English. The applicant must present proof of knowledge in English. Complete information on the eligibility requirements can be found in the local admission policy of KTH.

**Specific eligibility requirements**

A Swedish or foreign degree equivalent to Bachelor of Science of 180 university credits, with at least 45 university credits in mathematics. The students are required to have documented knowledge corresponding to basic university courses in analysis in one and several variables, linear algebra, numerical analysis, ordinary and partial differential equations and transforms, mathematical statistics, and basics of programming in a higher programming language.

**Selection process**
The selection process for the Master's programme in Applied and Computational Mathematics is based on a total evaluation of the following criteria: university, grade point average (GPA), course work related to the program (mathematics in a wide sense), and letter of motivation. Complete information on the eligibility requirements can be found in the local admission policy of KTH. The evaluation scale is 1-75.

**Implementation of the education**

**Structure of the education**

The duration of the academic year at KTH is 40 weeks. The academic year is divided into four periods. Each period lasts approximately seven weeks with at least 33 days of study. Each period is followed by an examination period. In addition to the four regular examination periods, there are four re-examination periods: at Christmas, in March, June and August, immediately before the start of the academic year. Teaching activities may, if necessary, be scheduled outside the academic year. Details about the structure follow the general rules stated by KTH.

**Courses**

The programme is course-based. Lists of courses are included in appendix 1.

At least 90 credits compulsory, conditional elective courses as well as degree work must be completed within the program level and track level, see the course and program directory.

The remaining approximately 30 credits consist of optional courses, where the following applies:

At least 15 credits are chosen among advanced level courses that have a strong connection to applied mathematics, examples are listed in the course list in the course and program directory.

To a certain extent, other courses may also be chosen: A maximum of 15 credits of the optional courses may consist of technical supplementary courses or broadening courses, i.e., courses in another technology area.

Note that the choice of optional courses must always be approved by the programme director.

**Grading system**

Courses in the first and the second cycle are graded on a scale from A to F. A-E are passing grades, A is the highest grade. The grades pass (P) and fail (F) are used for courses under certain circumstances.

Courses in the first and the second cycle are graded on a scale from A to F. A-E are passing grades, A is the highest grade. The grades pass (P) and fail (F) are used for courses under certain circumstances.

The grades pass (P) and fail (F) are used for thesis works.

**Conditions for participation in the programme**
Participation requires admission to courses within the programme and course registration. Course registration is done via the personal menu at www.kth.se

Before the second semester each student must select one of the four tracks: computational mathematics, optimization and systems theory, statistical learning and data analytics or financial mathematics.

For students starting their education from the autumn semester 2018, previous promotion requirements have been replaced with special admission requirements to each course. Admission requirements are specified in the course syllabus.

Course application

All programme students apply for courses 1-15 November/1-15 May for the next semester. The application is done via universityadmissions.se

**Recognition of previous academic studies**

Under certain circumstances, and in agreement with the programme director, credits for previous studies can be received according to the local policy of KTH.

**Studies abroad**

After approval by the programme director, part of the studies may be carried out abroad (including the Master’s degree project). The condition is that the parts of the programme carried out abroad should fit in with the educational programme.

**Degree project**

A 30-credit Master’s degree project is carried out at the end of the educational programme and may begin when special admission requirements for the course are fulfilled.

The purpose of the degree project is to develop the student's ability to perform independent project work, as well as to apply and deepen the skills obtained from the courses of the programme. The project may be carried out in an academic or industrial environment in Sweden or abroad.

The student must actively search for a suitable degree project; however KTH can provide some assistance with information on suitable points of contact. The choice of project must be approved by the programme director.

The degree project is graded with P/F.

**Degree**

In order to earn a Degree of Master of Science, passing grades in all courses which are included in the student’s study plan are required. The study plan must comprise 120 higher education credits which include a degree project consisting of 30 higher education credits, in the second cycle.
KTH’s local degree ordinance can be found at KTH's website, www.kth.se.

Appendix 1 - Course list
Appendix 2 - Programme syllabus descriptions
# Appendix 1: Course list

Master's Programme, Applied and Computational Mathematics, 120 credits (TTMAM), Programme syllabus for studies starting in autumn 2018

## General courses

### Year 1

#### Mandatory courses (22.5 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK2036</td>
<td>Theory and Methodology of Science with Applications</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td></td>
<td>(Natural and Technological Science)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF2520</td>
<td>Applied Numerical Methods</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2940</td>
<td>Probability Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

#### Optional courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB2280</td>
<td>Molecular Modeling</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>BB2300</td>
<td>Computational Chemistry</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>BB2441</td>
<td>Bioinformatics</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2257</td>
<td>Visualization</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2358</td>
<td>Introduction to High Performance Computing</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2365</td>
<td>Advanced Computation in Fluid Mechanics</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2421</td>
<td>Machine Learning</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>DD2435</td>
<td>Mathematical Modelling of Biological Systems</td>
<td>9.0 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF1811</td>
<td>Optimization</td>
<td>6.0 hp</td>
<td>First cycle</td>
</tr>
<tr>
<td>SF2521</td>
<td>Numerical Solutions of Differential Equations</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2522</td>
<td>Computational Methods for Stochastic Differential Equations</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2524</td>
<td>Matrix Computations for Large-scale Systems</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2561</td>
<td>The Finite Element Method</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>
SF2565  Program Construction in C++ for Scientific Computing  7.5 hp  Second cycle
SF2566  Advanced Individual Course in Scientific Computing  6.0 hp  Second cycle
SF2567  Project Course in Scientific Computing  7.5 hp  Second cycle
SF2568  Parallel Computations for Large- Scale Problems  7.5 hp  Second cycle
SF2701  Financial Mathematics, Basic Course  7.5 hp  Second cycle
SF2822  Applied Nonlinear Optimization  7.5 hp  Second cycle
SF2842  Geometric Control Theory  7.5 hp  Second cycle
SF2866  Applied Systems Engineering  7.5 hp  Second cycle
SF2930  Regression Analysis  7.5 hp  Second cycle
SF2935  Modern Methods of Statistical Learning  7.5 hp  Second cycle
SF2942  Portfolio Theory and Risk Management  7.5 hp  Second cycle
SF2943  Time Series Analysis  7.5 hp  Second cycle
SF2955  Computer Intensive Methods in Mathematical Statistics  7.5 hp  Second cycle
SF2956  Topological Data Analysis  7.5 hp  Second cycle
SF2957  Statistical Machine Learning  7.5 hp  Second cycle
SF2971  Martingales and Stochastic Integrals  7.5 hp  Second cycle
SF2972  Game Theory  7.5 hp  Second cycle
SF2975  Financial Derivatives  7.5 hp  Second cycle
SF2980  Risk Management  7.5 hp  Second cycle
SG2212  Computational Fluid Dynamics  7.5 hp  Second cycle
SG2224  Applied Computational Fluid Dynamics  5.0 hp  Second cycle

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2812</td>
<td>Applied Linear Optimization</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2832</td>
<td>Mathematical Systems Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2863</td>
<td>Systems Engineering</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

At least one of the conditionally elective courses has to be studied. The course/courses can be studies either during year one or two.

Note that due to overlap it is not possible to select both SF2935 and DD2421.

Year 2

Optional courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
</table>
BB2280 Molecular Modeling 7.5 hp Second cycle
BB2300 Computational Chemistry 7.5 hp Second cycle
BB2441 Bioinformatics 7.5 hp Second cycle
DD2358 Introduction to High Performance Computing 7.5 hp Second cycle
DD2421 Machine Learning 7.5 hp Second cycle
DD2435 Mathematical Modelling of Biological Systems 9.0 hp Second cycle
SF1811 Optimization 6.0 hp First cycle
SF2524 Matrix Computations for Large-scale Systems 7.5 hp Second cycle
SF2561 The Finite Element Method 7.5 hp Second cycle
SF2852 Optimal Control Theory 7.5 hp Second cycle
SF2866 Applied Systems Engineering 7.5 hp Second cycle
SF2935 Modern Methods of Statistical Learning 7.5 hp Second cycle
SF2942 Portfolio Theory and Risk Management 7.5 hp Second cycle
SF2980 Risk Management 7.5 hp Second cycle

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2832</td>
<td>Mathematical Systems Theory</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>SF2863</td>
<td>Systems Engineering</td>
<td>7.5 hp Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

At least one of the conditionally elective courses during year one and two has to be studied.

Note that due to overlap it is not possible to select both SF2935 and DD2421.

Track, Computational Mathematics (COMA)

Year 1

Mandatory courses (15.0 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2521</td>
<td>Numerical Solutions of Differential Equations</td>
<td>7.5 hp Second cycle</td>
</tr>
<tr>
<td>SF2568</td>
<td>Parallel Computations for Large- Scale Problems</td>
<td>7.5 hp Second cycle</td>
</tr>
</tbody>
</table>

Year 2

Mandatory courses (15.0 Credits)

Course
code  Course name  Credits Edu. level
SF2524  Matrix Computations for Large-scale Systems  7.5 hp  Second cycle
SF2561  The Finite Element Method  7.5 hp  Second cycle

**Track, Financial Mathematics (FMIA)**

**Year 1**

**Mandatory courses (7.5 Credits)**

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2701</td>
<td>Financial Mathematics, Basic Course</td>
<td>7.5 hp  Second cycle</td>
</tr>
</tbody>
</table>

**Conditionally elective courses**

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2930</td>
<td>Regression Analysis</td>
<td>7.5 hp  Second cycle</td>
</tr>
<tr>
<td>SF2943</td>
<td>Time Series Analysis</td>
<td>7.5 hp  Second cycle</td>
</tr>
</tbody>
</table>

**Supplementary information**

Among the conditionally elective courses at least one course from each year has to be studied: SF2943 or SF2930 and SF2975 or SF2980.

**Year 2**

**Mandatory courses (7.5 Credits)**

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2942</td>
<td>Portfolio Theory and Risk Management</td>
<td>7.5 hp  Second cycle</td>
</tr>
</tbody>
</table>

**Conditionally elective courses**

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2975</td>
<td>Financial Derivatives</td>
<td>7.5 hp  Second cycle</td>
</tr>
<tr>
<td>SF2980</td>
<td>Risk Management</td>
<td>7.5 hp  Second cycle</td>
</tr>
</tbody>
</table>

**Supplementary information**

Among the conditionally elective courses at least one course from each year has to be studied: SF2943 or SF2930 and SF2975 or SF2980.
Track, Optimization and Systems Theory (OPSA)

Year 1

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2812</td>
<td>Applied Linear Optimization</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2822</td>
<td>Applied Nonlinear Optimization</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2832</td>
<td>Mathematical Systems Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2842</td>
<td>Geometric Control Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2863</td>
<td>Systems Engineering</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2866</td>
<td>Applied Systems Engineering</td>
<td>7.5 hp</td>
<td>Second cycle</td>
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</tbody>
</table>

Supplementary information

At least 3 of the conditionally elective courses on the track has to be studied in addition to the already choosen conditionally elective course in the base block.

Year 2

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2832</td>
<td>Mathematical Systems Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2852</td>
<td>Optimal Control Theory</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2863</td>
<td>Systems Engineering</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2866</td>
<td>Applied Systems Engineering</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

At least 3 of the conditionally elective courses on the track has to be studied in addition to the already choosen conditionally elective course in the base block.

Track, Statistical Learning and Data Analytics (SIDA)

Year 1

Mandatory courses (15.0 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
</table>

Programme syllabus for Master's Programme, Applied and Computational Mathematics, 120 credits batch autumn 18. Appendix 1, page 5 of 6
SF2930  Regression Analysis 7.5 hp  Second cycle
SF2955  Computer Intensive Methods in Mathematical Statistics 7.5 hp  Second cycle

Supplementary information

This track replaces the track in Mathematical Statistics for students starting HT17.

Year 2

Mandatory courses (7.5 Credits)

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2935</td>
<td>Modern Methods of Statistical Learning</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Conditionally elective courses

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course name</th>
<th>Credits</th>
<th>Edu. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF2956</td>
<td>Topological Data Analysis</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
<tr>
<td>SF2957</td>
<td>Statistical Machine Learning</td>
<td>7.5 hp</td>
<td>Second cycle</td>
</tr>
</tbody>
</table>

Supplementary information

Among the conditionally elective courses at least one has to be studied.
Appendix 2: Specialisations

Master's Programme, Applied and Computational Mathematics, 120 credits (TTMAM), Programme syllabus for studies starting in autumn 2018

Track, Computational Mathematics (COMA)

The field of computer simulations is of great importance for high-tech industry and scientific/engineering research, e.g. virtual processing, climate studies, fluid dynamics, advanced materials, etc. Thus, Computational Science and Engineering (CSE) is an enabling technology for scientific discovery and engineering design. CSE involves mathematical modeling, numerical analysis, computer science, high-performance computing and visualization. The remarkable development of large scale computing in the last decades has turned CSE into the "third pillar" of science, complementing theory and experiment.

The track Computational Mathematics (COMA) is mainly concerned with the mathematical foundations of CSE. However, in this track we will also discuss issues of high-performance computing. Given the interdisciplinarity, your final curriculum may vary greatly depending on your interests.

Track, Financial Mathematics (FMIA)

Financial mathematics is applied mathematics used to analyze and solve problems related to financial markets. Any informed market participant would exploit an opportunity to make a profit without any risk of loss. This fact is the basis of the theory of arbitrage-free pricing of derivative instruments. Arbitrage opportunities exist but are rare. Typically both potential losses and gains need to be considered. Hedging and diversification aim at reducing risk. Speculative actions on financial markets aim at making profits. Market participants have different views of the future market prices and combine their views with current market prices to take actions that aim at managing risk while creating opportunities for profits. Portfolio theory and quantitative risk management present theory and methods that form the theoretical basis of market participants’ decision making.

Financial mathematics has received lots of attention from academics and practitioners over the last decades and the level of mathematical sophistication has risen substantially. However, a mathematical model is at best a simplification of the real world phenomenon that is being modeled, and mathematical sophistication can never replace common sense and knowledge of the limitations of mathematical modeling.

Track, Optimization and Systems Theory (OPSA)
**Optimization and Systems Theory** is a discipline in applied mathematics primarily devoted to methods of optimization, including mathematical programming and optimal control, and systems theoretic aspects of control and signal processing. The discipline is also closely related to mathematical economics and applied problems in operations research, systems engineering and control engineering.

Master’s education in Optimization and Systems Theory provides knowledge and competence to handle various optimization problems, both linear and nonlinear, to build up and analyze mathematical models for various engineering systems, and to design optimal algorithms, feedback control, and filters and estimators for such systems.

Optimization and Systems Theory has wide applications in both industry and research. Examples of applications include aerospace industry, engineering industry, radiation therapy, robotics, telecommunications, and vehicles. Furthermore, many new areas in biology, medicine, energy and environment, and information and communications technology require understanding of both optimization and system integration.

**Track, Statistical Learning and Data Analytics (SIDA)**

Statistics is the science of learning from data. Classical statistics is trying to understand data by determining a plausible model for data, and testing whether the data fits the model. Modern learning is concerned with computational statistics and automated methods for extracting information from data. As a result of technological progress and the emergence of massive data sets, a variety of scientific fields and their approaches to data analysis are converging at the interface of statistics and machine learning. This new field of “data analytics” focuses on modeling and knowledge extraction for predictive purposes. In statistical learning and data analytics, focus is on discovering new features in the data and on confirming or falsifying existing hypotheses. Predictive data analytics applies statistical models for predictive forecasting or classification. Data analytics, when it includes at its core mathematical statistics and computational learning, has the potential for transformative impact on science, business, and social sciences.