Linnæus University

Jnr: 2018/2404-3.1.1.3

Programme syllabus

Faculty of Technology

Matematikerprogrammet, 180 högskolepoäng
Applied Mathematics Programme, 180 credits

Level
First Level

Date of Ratification
Approved 2009-03-26
Revised 2018-09-07 by the Faculty Board within the Faculty of Technology
The programme syllabus is valid from autumn semester 2019

Prerequisites
General entry requirements and Mathematics 4, Physics 2 or Physics B, Mathematics D (Field-specific entry requirements 9/A9).

Description of Programme

The Applied Mathematics Programme is a bachelor programme with Mathematics as main subject.

An overall idea for the programme is that with sound knowledge in mathematics and good practice in programming the students are well prepared for deeper studies in applied mathematics. Knowledge from related subjects and potential applications of mathematics increases the attractivity of the mathematician on the labor market. Fields where mathematicians are demanded are for example information security, artificial intelligence, manufacturing engineering, economics and operations research, actuarial mathematics, design of experiments and statistic survey.

The program can also be considered as the first step towards a career in mathematics with the primary aim to obtain an advanced degree and then continue to work as a senior lecturer in mathematics.

The program can be studied in English.
Some optional courses are offered in Swedish only.

Objectives

Knowledge and understanding

For a Degree of Bachelor students must

- demonstrate knowledge and understanding in their main field of study, including knowledge of the scientific basis of the field, knowledge of applicable methods in the field, in-depth knowledge of some part of the field and a general sense of

current research issues.

Skills and abilities
For a Degree of Bachelor students must

- demonstrate an ability to seek, gather and critically interpret information that is relevant to a problem and to critically discuss phenomena, issues and situations;
- demonstrate an ability to independently identify, formulate and solve problems and to perform tasks within specified time limits;
- demonstrate an ability to present and discuss information, problems and solutions in dialogue with different groups, orally and in writing; and
- demonstrate the skills required to work independently in the field that the education concerns.

Judgement and approach
For a Degree of Bachelor students must

- demonstrate an ability to make assessments in their main field of study, taking into account relevant scientific, social and ethical aspects;
- demonstrate insight into the role of knowledge in society and into people's responsibility for how knowledge is used; and
- demonstrate an ability to identify their need of further knowledge and to upgrade their capabilities.

Programme specific goals
Knowledge and understanding
For the degree of Bachelor, the student should:

- show knowledge and understanding within the main field of Mathematics and Applied Mathematics

Skills and ability
For the degree of Bachelor the student should:

- show the ability to critically and systematically integrate knowledge in Mathematics and Applied Mathematics and analyse Mathematical models in fields of application such as Computer Science, Technology/Physics, and Economics
- show the ability to critically, independently and creatively, identify problem issues within fields of application such as Computer Science, Economics or Technology/Physics and be able to build mathematical models for them.

Judgement and Approach
For the degree of Bachelor, the student should

- show the ability within Mathematics and Applied Mathematics to make evaluations with respect to relevant scientific, social, and ethical aspects.

Content

Programme Overwiew
The degree programme comprises of 180 credits and includes a final Bachelor's degree project which comprises 15 credits. The programme has four separate specializations: (1) Mathematics, (2) Engineering mathematics, (3) Computer Science and Statistics, (4) Economics and Operations Research. The specializations share a core of courses in matematics (90 credits) and computer science (15 credits). The first year all specializations study the same courses exept for one course at the end of year one. In addition to compulsory courses within each specialization, each specialization also

contains a specified set of elective courses corresponding to the equivalent of 15 to 30 credits depending on the specialization.

Besides courses in mathematical analysis and algebra, the core set of courses include mathematical modeling, numerical methods, optimaization methods, transfom methods, statistics and programming. In most courses the studens also use mathematical software and work with problem solving and modelling from applications in Computer Science, Technology, Physics, Economics and Operations Research; it will give a deeper understanding for the subject and it role in the deveopment of new technologies and societal development. Within the specializations the studens can deepen this knowlege by studing courses from Engineering, Computer Science, Statistics, Economics and Operations Research or Mathematics.

In the *Mathematics specialization* the students can deepen their knowledge in algebra, analysis and mathematical statistics. They may also study elective courses in Economics, Signal Processing, Physics and Computer Science.

In the Engineering Mathematics specialization as well as in all other specializations the students are trained to work with analytical and numerical methods in modelling and simulation of systems in Engineering, Physics, Economics and Operations Research. In the Engineering Mathematics specialization the students can broaden and deepen such knowledge and skills in compulsory courses in Mechanics, Thermodynamics and Statistical Physics, Intermediate Microeconomics, Signal Processing, Automatic Control Theory, and Machine Learning. They also have elective courses in Mechanics of Materials, Signal Processing, Economics, Mathematical Statistics, and Production Technology.

In the *Computer Science and Statistics specialization* as well as in all other specializations the students are trained to work with modelling and simulation of discrete systems with applications in systems in Statistical Data Analysis, Network Optimization, Computer Graphics, and Computer Vision. In the Computer Science specialization the students can broaden and deepen such knowledge and skills in compulsory courses in Cryptography and Coding, Data Base Theory, Signal Processing and Machine Learning. They also have elective courses in Computer Graphics, Automatic Control, Software Development, Production Technology, and Mathematical Statistics, e.g Bayesian Methods with special applications in computer vision and pattern recognition.

The *Economics and Operations Research specialization* as well as all other specializations include courses in Discrete Mathematics, Linear Algebra, Optimization Methods, Stochastic Processes. It serves as a basis in Operations Research which concerns mathematical tools for Management Science, economical analysis, optimization and simulation of complex systems, algorithms for decision making and artificial intelligence. In the Economics and Operations Research specialization the students can broaden and deepen such knowledge and skills in compulsory courses in Intermediate Microeconomics, Production Economics, and Machine Learning. They also have elective courses in Economics, Corporate Finance, and Mathematical Statistics.

All specializations contain content related to sustainable development. Especially, issues regarding sustainability are contained in the compulsory courses in Optimization Methods and Mathematics, Science and Society. All specializations include an elective course in Life Cycle Analysis. The Engineering Mathematics specialization contains a compulsory course in Thermodynamics and Statistical Physics which covers issues in energy supply management and energy resources in society.

Mathematical communication skills are trained in laborations, assignments and project work. Starting from the second semester, each semester includes at least one project assignment.

During the programme, the progression of the students is followed up both concerning the individual courses and the whole programme, and the progression is evaluated against the aims of the objectives.

Programme courses

#=The course is compulsory in all of the specializations

**=Course in the main field of study*

Specialization Mathematics
Note that for bachelor degree at least 30 credits outside the main field of study is required. Therefore, at least 2 elective courses summing up to a total of 15 credits in the mathematics specialization must be chosen in another field than Mathematics.
Year 1 (Autumn term)

- #Discrete Mathematics and Mathematical Thinking, 7.5 credits (G1N)* A main purpose of the course is to give an introduction to discrete mathematics with applications in computer science, probability theory and operations research. Another main purpose is preparation for further studies in mathematics, programming and the use of mathematical software. The course also includes special training in mathematical thinking for problem solving, modelling, writing and mathematical reasoning.
- #Calculus I, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to differential calculus in one variable. Theory and methods are illustrated by examples from applications in for example physics, economics and population dynamics.
- #Linear Algebra, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to linear algebra and its applications with relevance for the different specializations of the program. Theory and methods are illustrated by examples from applications in mechanics, harmonic motion, electrical networks, data adaption, economics and operations research. The students will use mathematical software in problem solving and visualization.
- #Programming and Problem Solving, 7.5 credits (G1N) The main purpose of the course is to give an introduction to programming and object orientated programming technique.

Year 1 (Spring term)

- #Analysis II, 7.5 credits (G1F)* The main purpose of the course is to give an introduction to integral calculus, series and differential equations in one variable. Some exercises involve using mathematical software to approximate series and integrals. In assignments the students practice mathematical writing. After completing the course the students should be able to describe and prove central theorems regarding integral calculus and converengence of series.
- #Programming and Data Structures, 7.5 credits (G1N) The aim of the course is to give an insight into object-oriented modelling, e.g. inheritance and polymorphism, and an introduction to algorithms and data structures.
- #Probaility and Statistics, 7.5 credits (G1F)* The overall aim of the course is to give an introduction to probability theory and statistical methodology. This includes problem solving and modelling with random models and utilization of observed data to draw conclusions. Theory and method are illustrated by examples and problems from applications in data analysis, strength of materials, quality control, economics and operations research. Visualization and problem solving using mathematical software are important ingredients in the course. The course also includes project work and report writing.
- Electives: Mechanics (in swedish), 7.5 credits (G1N) alt. Cryptography and Coding Theory, 7.5 credits (G1F)*.

Year 2 (Autumn term)

- #Multivariable Calculus and Vector Calculus, 7.5 credits (G1F)* The overall aim of the course is to provide an introduction to multivariable calculus and vector calculus. Theory and method are illustrated by examples from applications in mathematical statistics, mechanics, fluid dynamics, and electromagnetic field theory. The course is preparatory for further studies in optimization methods, mathematical statistics, transform methods and complex analysis, numerical methods, machine learning, and differential equations.
- Algebraic Structures I, 7.5 credits (G2F)* The purpose of the course is to introduce algebraic structures like groups, rings and fields as well as proof techniques in algebra. The course is preparatory for further studies in algebra, crytography and coding theory.
- #Optimization Methods, 7.5 credits (G2F)* The over all aim of the course is to introduce methods of optimization and operations research used in management, computer science, engineering and economics. Another aim is to increase the students' knowledge in multivariable analysis and linear algebra, e.g. regarding symmetrical matrices, spectral theory and quadratic forms. Particular importance is given to the formulation and modelling of real problems in order for the participants to later use the methods in working life. In particular, optimization problems are studied that are relevant to sustainable development and resource allocation. Problem solving with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Electives: Algebraic Structures II, 7.5 credits (A1N)* alt. Intermediate Microeconomics, 7.5 credits (G1F) alt. Database Theory, 7.5 credits (G2F)

Year 2 (Spring term)

- #Numerical Methods, Modelling and Linear Algebra, 10 credits (G2F)* A main purpose of the course is to introduce methods for numerical solutions of mathematical problems and analyze their theoretical and computational properties. Practical work with problem solving and visualization with mathematical software is a key component of the course. The course also includes a project work in a tentative field of application such as the strength of materials, signal processing, data compression, search engines, robotics or financial mathematics. A second main purpose is to develop further and deepen the students' knowledge in linear algebra with applications in scientific computing. Topics covered with repect to this goal include, but is not restricted to, orthogonality and inner product spaces, diagonalization and the decoupling principle, singular value decomposition and principal component analysis, matrix norms and condition numbers. The course is preparatory for further studies in computational mathematics, linear algebra, machine learning, differential equations, and advanced calculus.
- #Mathematics, Science and Society, 5 credits (G2F)* The aim of the course is to provide students with basic knowledge of scientific theory, ethics, scientific presentation, and knowledge of mathematics in social challenges and sustainable social development.
- #Fourier Methods and Complex Analysis 7.5 credits (G2F)* A main purpose of the course is to give an introduction to transform methods, fourier series, and complex analysis with applications in engineering, mathematical statistics and finance. A second main purpose is that the students should develop further and deepen their knowledge in analysis. The course is preparatory for further studies in e.g. signal processing, automatic control, differential equations, stochastic processes, time series analysis and image analysis.
- Electives: Machine Learning, 7.5 credits (G1F) alt. Linear Statistical Models, 7.5 credits (G1F)* alt. Bayesian Methods, 7.5 credits (G2F)* alt. Cryptography and

Coding Theory, 7.5 credits (G1F)* alt. Supply Chain Management, 7.5 credits (G1N) alt. Mechanics (in swedish), 7.5 credits (G1N).

Year 3 (Autumn term)

- #Ordinary Differential Equations, 7.5 credits (G2F)* The aim of the course is to develop further and deepen the students' knowledge regarding differential equations, especially systems of ordinary differential equations and stability theory, and its applications in mathematical modelling. The theory is illustrated by examples from applications in areas such as thermodynamics, mechanics, automatic control, and population dynamics. Skills in mathematical modelling, numerical computation using mathematical software, and mathematical communication are trained in mandatory project assignments.
- Calculus, Advanced Course, 7.5 credits (G2F)* The aim of the course is to develop further and deepen the students knowledge in analysis and function theory.
- #Stochastic Processes, 7.5 credits (G2F)* The over all aim of the course is to develop further and deepen the students' knowledge of theoretical concepts and methods in probability theory, especially Markov processes in discrete and continuous time, queueing theory, branching processes, time series and spectral density. Particular importance is given to the formulation, modelling and simulation of real problems and problem solving from operations research applications (such as inventory, life expectancy, reliability, quality technology, forecast and simulation), signal processing and population growth. Problem solving and simulation with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Electives: Algebraic Structures II, 7.5 credits (A1N)* alt. Database Theory, 7.5 credits (G2F) alt. Signal Processing, 7.5 credits (A1N), 7.5 credits (G2F) alt. Intermediate Microeconomics, 7.5 credits (G1F) alt. Portfolio Choice Theory, 7.5 credits (G1F) alt. Corporate Finance, 7.5 credits (G2F) alt. Life Cycle Analysis, 7.5 credits (A1N).

Year 3 (Spring term)

- Degree Project in Mathematics at Bachelor Level, 15 credits (G2E)* The purpose of the Degree project is that the student should apply the acquired knowledge on a problem in pure or applied mathematics.
- Electives: Montecarlo Methods, 7.5 credits (A1N) alt. Introductory Financial Mathematics, 7,5 credits (G1F)* alt. Sofware Engineering, 7.5 credits (G1N).
- Electives: Bayesian methods, 7.5 credits (G2F)* alt. Linear Statistical Models, 7.5 credits (G1F)* alt. Cryptography and Coding Theory, 7.5 credits (G1F)* alt. Machine Learning, 7.5 credits (G1F) alt. Supply chain management, 7.5 credits (G1N) alt. Mechanics (in swedish), 7.5 credits (G1N).

#=The course is compulsory in all of the specializations

*=main field course.

Specialization Engineering Mathematics

Year 1 (Autumn term)

- #Discrete Mathematics and Mathematical Thinking, 7.5 credits (G1N)* A main purpose of the course is to give an introduction to discrete mathematics with applications in computer science, probability theory and operations research. Another main purpose is preparation for further studies in mathematics,

programming and the use of mathematical software. The course also includes special training in mathematical thinking for problem solving, modelling, writing and mathematical reasoning.
- #Calculus I, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to differential calculus in one variable. Theory and methods are illustrated by examples from applications in for example physics, economics and population dynamics.
- #Linear Algebra, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to linear algebra and its applications with relevance for the different specializations of the program. Theory and methods are illustrated by examples from applications in mechanics, harmonic motion, electrical networks, data adaption, economics and operations research. The students will use mathematical software in problem solving and visualization.
- #Programming and Problem Solving, 7.5 credits (G1N) The main purpose of the course is to give an introduction to programming and object orientated programming technique.

Year 1 (Spring term)

- #Analysis II, 7.5 credits (G1F)* The main purpose of the course is to give an introduction to integral calculus, series and differential equations in one variable. Some exercises involve using mathematical software to approximate series and integrals. In assignments the students practice mathematical writing. After completing the course the students should be able to describe and prove central theorems regarding integral calculus and converengence of series.
- #Programming and Data Structures, 7.5 credits (G1N) The aim of the course is to give an insight into object-oriented modelling, e.g. inheritance and polymorphism, and an introduction to algorithms and data structures.
- #Probaility and Statistics, 7.5 credits (G1F)* The overall aim of the course is to give an introduction to probability theory and statistical methodology. This includes problem solving and modelling with random models and utilization of observed data to draw conclusions. Theory and method are illustrated by examples and problems from applications in data analysis, strength of materials, quality control, economics and operations research. Visualization and problem solving using mathematical software are important ingredients in the course. The course also includes project work and report writing.
- Mechanics (in swedish), 7.5 credits (G1N) The course content cover topics like statics, dynamics and rotaional dynamics, and preservation laws.

Year 2 (Autumn term)

- #Multivariable Calculus and Vector Calculus, 7.5 credits (G1F)* The overall aim of the course is to provide an introduction to multivariable calculus and vector calculus. Theory and method are illustrated by examples from applications in mathematical statistics, mechanics, fluid dynamics, and electromagnetic field theory. The course is preparatory for further studies in optimization methods, mathematical statistics, transform methods and complex analysis, numerical methods, machine learning, and differential equations.
- Thermodynamics and Statistical Physics, 7,5hp (G1F) The over all purpose of the course is to give an introduction to thermodynamics and statistical physics using concepts from mathematical statistics and multivariable calculus. The content includes among other things energy transport, the heat equation, energy supply and energy resources in society. In addition to theory the students train their understanding regarding measurement and observation and the different roles that theory and experiment have in physics, as well as their skills regarding planning and performing experiments, simulation and scientific communication.
- #Optimization Methods, 7.5 credits (G2F)* The over all aim of the course is to introduce methods of optimization and operations research used in management,

computer science, engineering and economics. Another aim is to increase the students' knowledge in multivariable analysis and linear algebra, e.g. regarding symmetrical matrices, spectral theory and quadratic forms. Particular importance is given to the formulation and modelling of real problems in order for the participants to later use the methods in working life. In particular, optimization problems are studied that are relevant to sustainable development and resource allocation. Problem solving with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.

- Intermediate Microeconomics, 7.5 credits (G1F) The purpose of the course is to study microeconomic theory using mathematical tools like optimization and game theory. The course content covers consumer theory, market equilibrium, production theory, analysis of the effect of various market structures, game theory, effects of external factors affecting markets, uncertainty and asymmetric information. The course is preparatory for further studies in economics.

Year 2 (Spring term)

- #Numerical Methods , Modelling and Linear Algebra, 10 credits (G2F)* A main purpose of the course is to introduce methods for numerical solutions of mathematical problems and analyze their theoretical and computational properties. Practical work with problem solving and visualization with mathematical software is a key component of the course. The course also includes a project work in a tentative field of application such as the strength of materials, signal processing, data compression, search engines, robotics or financial mathematics. A second main purpose is to develop further and deepen the students' knowledge in linear algebra with applications in scientific computing. Topics covered with repect to this goal include, but is not restricted to, orthogonality and inner product spaces, diagonalization and the decoupling principle, singular value decomposition and principal component analysis, matrix norms and condition numbers. The course is preparatory for further studies in computational mathematics, linear algebra, machine learning, differential equations, and advanced calculus.
- #Mathematics, Science and Society, 5 credits (G2F)* The aim of the course is to provide students with basic knowledge of scientific theory, ethics, scientific presentation, and knowledge of mathematics in social challenges and sustainable social development.
- #Fourier Methods and Complex Analysis 7.5 credits (G2F)* A main purpose of the course is to give an introduction to transform methods, fourier series, and complex analysis with applications in engineering, mathematical statistics and finance. A second main purpose is that the students should develop further and deepen their knowledge in analysis. The course is preparatory for further studies in e.g. signal processing, automatic control, differential equations, stochastic processes, time series analysis and image analysis.
- #Machine Learning, 7.5 credits (G1F) The aim of the course is to give an introduction to the theory and practice related to machine learning. After the course, the student should understand and be able to apply machine learning methods to handle various types of problems in, among other things, statistical data analysis, operations research and artificial intelligence.

Åk 3 (Autumn term)

- #Ordinary Differential Equations, 7.5 credits (G2F)* The overall aim of the course is to develop further and deepen the students' knowledge regarding differential equations, especially systems of ordinary differential equations and stability theory, and its applications in mathematical modelling. The theory is illustrated by examples from applications in areas such as thermodynamics, mechanics, automatic control, and population dynamics. Skills in mathematical

modelling, numerical computation using mathematical software, and mathematical communication are trained in mandatory project assignments.

- Automatic Control, 7.5 credits (G2F) The aim of the course is to provide basic knowledge of the principles of Automatic control. The dynamic systems being processed are all time-continuous and time-varied. With some exceptions, they are also linear. In the course, systems and regulators are modelled, and the regulated systems are analyzed.
- #Stochastic Processes, 7.5 credits (G2F)* The over all aim of the course is to develop further and deepen the students' knowledge of theoretical concepts and methods in probability theory, especially Markov processes in discrete and continuous time, queueing theory, branching processes, time series and spectral density. Particular importance is given to the formulation, modelling and simulation of real problems and problem solving from operations research applications (such as inventory, life expectancy, reliability, quality technology, forecast and simulation), signal processing and population growth. Problem solving and simulation with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Electives: Solid Mechanics, 7.5 credits (G1F) alt. Signal Processing, 7.5 credits (A1N) alt. Portfolio Choice Theory, 7.5 credits (G1F) alt. Corporate Finance, 7.5 credits (G2F) alt. Database thory, 7.5 credits (G2F)* alt. Life Cycle Analysis, 7.5 credits (A1N).

Year 3 (Spring term)

- Degree project, 15 credits (G2E) *The purpose of the Bachelor’s essay is that the student should apply the acquired knowledge on a problem in pure or applied mathematics.
- Electives: Montecarlo Methods, 7.5 credits (A1N) alt. Automatic Control, Advanced Course, 7.5 credits (A1N) alt. Software engineering, 7.5 credits (G1N).
- Electives: Bayesian Methods, 7.5 credits (G2F)* alt. Linear Statistical Models, 7.5 credits (G2F)* alt. Supply chain management , 7.5 credits (G1N) alt. Cryptography and Coding Theory, 7.5 credits (G1F)*.

#=The course is compulsory in all of the specializations

*=main field course.

Specialization Computer Science and Statistics

Year 1 (Autumn term)

- #Discrete Mathematics and Mathematical Thinking, 7.5 credits (G1N)* A main purpose of the course is to give an introduction to discrete mathematics with applications in computer science, probability theory and operations research. Another main purpose is preparation for further studies in mathematics, programming and the use of mathematical software. The course also includes special training in mathematical thinking for problem solving, modelling, writing and mathematical reasoning.
- #Calculus I, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to differential calculus in one variable. Theory and methods are illustrated by examples from applications in for example physics, economics and population dynamics.
- #Linear Algebra, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to linear algebra and its applications with relevance for the different specializations of the program. Theory and methods are illustrated by examples from applications in mechanics, harmonic motion, electrical networks, data

adaption, economics and operations research. The students will use mathematical software in problem solving and visualization.
- #Programming and Problem Solving, 7.5 credits (G1N) The main purpose of the course is to give an introduction to programming and object orientated programming technique.

Year 1 (Spring term)

- #Analysis II, 7.5 credits (G1F)* The main purpose of the course is to give an introduction to integral calculus, series and differential equations in one variable. Some exercises involve using mathematical software to approximate series and integrals. In assignments the students practice mathematical writing. After completing the course the students should be able to describe and prove central theorems regarding integral calculus and converengence of series.
- #Programming and Data Structures, 7.5 credits (G1N) The aim of the course is to give an insight into object-oriented modelling, e.g. inheritance and polymorphism, and an introduction to algorithms and data structures.
- #Probaility and Statistics, 7.5 credits (G1F)* The overall aim of the course is to give an introduction to probability theory and statistical methodology. This includes problem solving and modelling with random models and utilization of observed data to draw conclusions. Theory and method are illustrated by examples and problems from applications in data analysis, strength of materials, quality control, economics and operations research. Visualization and problem solving using mathematical software are important ingredients in the course. The course also includes project work and report writing.
- Cryptography and Coding Theory, 7.5 hp (G1F)*.

Year 2 (Fall term)

- #Multivariable Calculus and Vector Calculus, 7.5 credits (G1F)* The overall aim of the course is to provide an introduction to multivariable calculus and vector calculus. Theory and method are illustrated by examples from applications in mathematical statistics, mechanics, fluid dynamics, and electromagnetic field theory. The course is preparatory for further studies in optimization methods, mathematical statistics, transform methods and complex analysis, numerical methods, machine learning, and differential equations.
- Electives: Internet Security, 7.5 credits (G1F) alt. Computer Graphics, 7,5 credits (G1N).
- #Optimization Methods, 7.5 credits (G2F)* The over all aim of the course is to introduce methods of optimization and operations research used in management, computer science, engineering and economics. Another aim is to increase the students' knowledge in multivariable analysis and linear algebra, e.g. regarding symmetrical matrices, spectral theory and quadratic forms. Particular importance is given to the formulation and modelling of real problems in order for the participants to later use the methods in working life. In particular, optimization problems are studied that are relevant to sustainable development and resource allocation. Problem solving with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Database Theory, 7.5 credits (G2F) The course provides a technical and conceptual basis for database systems by studying database models, database modelling, relational algebra, storage structures, SQL and other partially visual query languages as well as visual database interfaces.

Year 2 (Spring term)

- #Numerical Methods, Modelling and Linear Algebra, 10 credits (G2F)* A main purpose of the course is to introduce methods for numerical solutions of

mathematical problems and analyze their theoretical and computational properties. Practical work with problem solving and visualization with mathematical software is a key component of the course. The course also includes a project work in a tentative field of application such as the strength of materials, signal processing, data compression, search engines, robotics or financial mathematics. A second main purpose is to develop further and deepen the students' knowledge in linear algebra with applications in scientific computing. Topics covered with repect to this goal include, but is not restricted to, orthogonality and inner product spaces, diagonalization and the decoupling principle, singular value decomposition and principal component analysis, matrix norms and condition numbers. The course is preparatory for further studies in computational mathematics, linear algebra, machine learning, differential equations, and advanced calculus.

- #Mathematics, Science and Society, 5 credits (G2F)* The aim of the course is to provide students with basic knowledge of scientific theory, ethics, scientific presentation, and knowledge of mathematics in social challenges and sustainable social development.
- #Fourier Methods and Complex Analysis 7.5 credits (G2F)* A main purpose of the course is to give an introduction to transform methods, fourier series, and complex analysis with applications in engineering, mathematical statistics and finance. A second main purpose is that the students should develop further and deepen their knowledge in analysis. The course is preparatory for further studies in e.g. signal processing, automatic control, differential equations, stochastic processes, time series analysis and image analysis.
- #Machine Learning, 7.5 credits (G1F) The aim of the course is to give an introduction to the theory and practice related to machine learning. After the course, the student should understand and be able to apply machine learning methods to handle various types of problems in, among other things, statistical data analysis, operations research and artificial intelligence.

Year 3 (Fall term)

- Algebraic Structures I, 7.5 credits (G2F)* The purpose of the course is to introduce algebraic structures like groups, rings and fields as well as proof techniques in algebra. The course is preparatory for further studies in algebra, crytography and coding theory.
- Electives: Multivariate Analysis, 7.5 credits (A1N)* alt. Internet Security, 7.5 credits (G2F) alt. Computer Graphics, 7.5 credits (G1F) alt. Automatic Control, 7.5 credits (G2F) alt. Engineering Economics (in swedish), 7.5 credits (G1N) alt. Thermodynamics and Statistical Physics, 7.5 credits (G1F) alt. Ordinary Differential Equations, 7.5 credits (G2F)*.
- #Stochastic Processes, 7.5 credits (G2F)* The over all aim of the course is to develop further and deepen the students' knowledge of theoretical concepts and methods in probability theory, especially Markov processes in discrete and continuous time, queueing theory, branching processes, time series and spectral density. Particular importance is given to the formulation, modelling and simulation of real problems and problem solving from operations research applications (such as inventory, life expectancy, reliability, quality technology, forecast and simulation), signal processing and population growth. Problem solving and simulation with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Electives: Algebraic Structures II, 7.5 hp (A1N)* alt. Signal Processing, 7.5 credits (A1N) alt. Intermediate microeconomic analysis, 7.5 credits (G1F) alt. Portfolio Choice Theory, 7.5 credits (G1F) alt. Corporate Finance, 7.5 credits (G2F) alt. Life Cycle Analysis, 7.5 credits (A1N).

Year 3 (Spring term)

- #Degree project, 15 credits (G2E)* The purpose of the Bachelor's essay is that the student should apply the acquired knowledge on a problem in pure or applied mathematics.
- Electives: Introductory Financial Mathematics, 7,5 credits (G1F)*. Montecarlo Methods, 7.5 credits (A1N) alt. Automatic Control, Advanced Course, 7.5 credits (A1N) alt. Sofware Engineering, 7.5 credits (G1N).
- Electives: Bayesian Methods, 7,5 credits (G2F)* alt Linear Statistical Models, 7.5 credits (G1F)* alt. Mechanics (in swedish), 7.5 credits (G1N).

#=The course is compulsory in all of the specializations

*=main field course

Specialization Economics and Operations Research

Year 1 (Fall term)

- #Discrete Mathematics and Mathematical Thinking, 7.5 credits (G1N)* A main purpose of the course is to give an introduction to discrete mathematics with applications in computer science, probability theory and operations research. Another main purpose is preparation for further studies in mathematics, programming and the use of mathematical software. The course also includes special training in mathematical thinking for problem solving, modelling, writing and mathematical reasoning.
- #Calculus I, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to differential calculus in one variable. Theory and methods are illustrated by examples from applications in for example physics, economics and population dynamics.
- #Linear Algebra, 7.5 credits (G1N)* The main purpose of the course is to give an introduction to linear algebra and its applications with relevance for the different specializations of the program. Theory and methods are illustrated by examples from applications in mechanics, harmonic motion, electrical networks, data adaption, economics and operations research, e.g. the Leontief Input-Output Model. The students will use mathematical software in problem solving and visualization.
- #Programming and Problem Solving, 7.5 credits (G1N) The main purpose of the course is to give an introduction to programming and object orientated programming technique.

Year 1 (Spring term)

- #Analysis II, 7.5 credits (G1F)* The main purpose of the course is to give an introduction to integral calculus, series and differential equations in one variable. Some exercises involve using mathematical software to approximate series and integrals. In assignments the students practice mathematical writing. After completing the course the students should be able to describe and prove central theorems regarding integral calculus and converengence of series.
- #Programming and Data Structures, 7.5 credits (G1N) The aim of the course is to give an insight into object-oriented modelling, e.g. inheritance and polymorphism, and an introduction to algorithms and data structures.
- #Probaility and Statistics, 7.5 credits (G1F)* The overall aim of the course is to give an introduction to probability theory and statistical methodology. This includes problem solving and modelling with random models and utilization of observed data to draw conclusions. Theory and method are illustrated by examples and problems from applications in data analysis, strength of materials, quality control, economics and operations research. Visualization and problem solving using mathematical software are important ingredients in the course. The

course also includes project work and report writing.
- Supply Chain Management, 7.5 credits (G1N) The oveall aim of the course is to develop the students understanding of the linkage between purchase and logistics.

Year 2 (Fall term)

- #Multivariable Calculus and Vector Calculus, 7.5 credits (G1F)* The overall aim of the course is to provide an introduction to multivariable calculus and vector calculus. Theory and method are illustrated by examples from applications in mathematical statistics, mechanics, fluid dynamics, and electromagnetic field theory. The course is preparatory for further studies in optimization methods, mathematical statistics, transform methods and complex analysis, numerical methods, machine learning, and differential equations.
- Electives: Engineering Economics (in swedish), 7.5 credits (G1N) alt. Economics and Operational Management, 7.5 credits (G1N).
- #Optimization Methods, 7.5 credits (G2F)* The over all aim of the course is to introduce methods of optimization and operations research used in management, computer science, engineering and economics. Another aim is to increase the students' knowledge in multivariable analysis and linear algebra, e.g. regarding symmetrical matrices, spectral theory and quadratic forms. Particular importance is given to the formulation and modelling of real problems in order for the participants to later use the methods in working life. In particular, optimization problems are studied that are relevant to sustainable development and resource allocation. Problem solving with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Intermediate Microeconomics, 7.5 credits (G1F) The purpose of the course is to study microeconomic theory using mathematical tools like optimization and game theory. The course content covers consumer theory, market equilibrium, production theory, analysis of the effect of various market structures, game theory, effects of external factors affecting markets, uncertainty and asymmetric information. The course is preparatory for further studies in economics.

Year 2 (Spring term)

- #Numerical Methods and Linear Algebra, 10 credits (G2F)* A main purpose of the course is to introduce methods for numerical solutions of mathematical problems and analyze their theoretical and computational properties. Practical work with problem solving and visualization with mathematical software is a key component of the course. The course also includes a project work in a tentative field of application such as the strength of materials, signal processing, data compression, search engines, robotics or financial mathematics. A second main purpose is to develop further and deepen the students' knowledge in linear algebra with applications in scientific computing. Topics covered with repect to this goal include, but is not restricted to, orthogonality and inner product spaces, diagonalization and the decoupling principle, singular value decomposition and principal component analysis, matrix norms and condition numbers. The course is preparatory for further studies in computational mathematics, linear algebra, machine learning, differential equations, and advanced calculus.
- #Mathematics, Science and Society, 5 credits (G2F)* The aim of the course is to provide students with basic knowledge of scientific theory, ethics, scientific presentation, and knowledge of mathematics in social challenges and sustainable social development.
- #Fourier Methods and Complex Analysis 7.5 credits (G2F)* A main purpose of the course is to give an introduction to transform methods, fourier series, and complex analysis with applications in engineering, mathematical statistics and finance. A second main purpose is that the students should develop further and deepen their knowledge in analysis. The course is preparatory for further studies

in e.g. signal processing, automatic control, differential equations, stochastic processes, time series analysis and image analysis.
- #Machine Learning, 7.5 credits (G1F) The aim of the course is to give an introduction to the theory and practice related to machine learning. After the course, the student should understand and be able to apply machine learning methods to handle various types of problems in, among other things, statistical data analysis, operations research and artificial intelligence.

Year 3 (Fall term)

- #Ordinary Differential Equations, 7.5 credits (G2F)* The aim of the course is to develop further and deepen the students' knowledge regarding differential equations, especially systems of ordinary differential equations and stability theory, and its applications in mathematical modelling. The theory is illustrated by examples from applications in areas such as thermodynamics, mechanics, automatic control, and population dynamics. Skills in mathematical modelling, numerical computation using mathematical software, and mathematical communication are trained in mandatory project assignments.
- Electives: Public Economics, 7,5 credits (G1F) alt. Environmental Economics and Resource Allocation**,** 7.5 credits (G2F) alt. Multivariate Analysis, 7.5 credits (A1N)* alt. Theermodynamics and Statistical Physics, 7.5 credits (G1F) alt. Automatic Control, 7.5 credits (G2F).
- #Stochastic Processes, 7.5 credits (G2F)* The over all aim of the course is to develop further and deepen the students' knowledge of theoretical concepts and methods in probability theory, especially Markov processes in discrete and continuous time, queueing theory, branching processes, time series and spectral density. Particular importance is given to the formulation, modelling and simulation of real problems and problem solving from operations research applications (such as inventory, life expectancy, reliability, quality technology, forecast and simulation), signal processing and population growth. Problem solving and simulation with mathematical software are important ingredients of the course. Skills in mathematical modelling and mathematical communication are trained in mandatory project assignments.
- Electives: Portfolio Choice Theory, 7,5 credits (G1F) alt. Corporate Finance, 7,5 credits (G2F) alt. Marketing, 7,5 credits (G1N) alt. Life Cycle Analysis, 7,5 credits (A1N) alt. Database Theory, 7.5 credits (G2F)*.

Year 3 (Spring term)

- Degree project, 15 credits (G2E) *The purpose of the Bachelor’s essay is that the student should apply the acquired knowledge on a problem in pure or applied mathematics.
- Electives: Montecarlo Methods, 7.5 credits (A1N)* alt. Sofware Engineering, 7.5 credits (G1N) alt. Reliability and maintenance technology, 7.5 credits (G1F) alt. Material Planning and Production Control, 7.5 credits (G1N) alt. Introductory Financial Mathematics, 7,5 credits (G1F)*alt. Entrepeneurship and Buisiness Development, 7.5 credits (G1F) alt. Organisation and Leadership, 7.5 credits (G1N).
- Electives: Marketing, 7.5 credits (G1N) alt. Production Technology, 7.5 credits (G1F) The overall aim of the course is to provide knowledge and understanding in efficient production technology. Topics covered include production systems and universal principles for production, flow theory, modelling, simulation and analysis of flow in production system using software like SIMIO or the equivalent, introduction to Industry 4.0, robotization and automation. The course is preparatory for further studies in stochastic processes and simulation.Linear statistical models, 7.5 credits (G1F)*Linear Statistical Models, 7.5 credits (G1F)* alt. Bayesian Methods, 7,5 credits (G2F)* alt. Mechanics (in swedish), 7.5 credits (G1N) alt Cryptography and Coding Theory, 7.5 credits (G1F)*.

The courses may be offered in different semesters than listed above.

Societal relevance

All students have opportunities to develop contacts with local trade and industrial representatives. These contacts are in the form of educational visits, projects, seminars etc. The seminars are primarily of contact-seeking nature, where business issues are in focus, but general issues also arise. The main contact takes place in the course Mathematics, Science and Society. In addition to contacts with business, students also gain insight into mathematical work in the public sector. For some students, contact is made with employers in the final degree project, for many, this is designed as a bridge to a future occupational business or public sector professions.

Internationalization

Following consultation with the programme director, part of the programme can be pursued at a university abroad. The programme director decides if the courses at another university abroad are relevant for the programme specialization and can approve that such courses can replaces some courses in the programme.

Scope of the programme

On the basis of examples, assignments and the degree dissertation project, students' awareness of sustainable development, gender, equality and diversity and internationalization will be raised. Mathematics is a particularly suitable subject for internationalization. Mathematics is an international language.

In all specialization, elements of sustainable development are included. In particular, sustainability perspectives are considered in compulsory courses such as Optimization Methods and Mathematics, Science and Society. In all directions, one can choose the course in life cycle analysis for the third year. Within the field of technical mathematics there is also a course in thermodynamics and statistical physics that contains elements of energy supply and energy resources in society.

In mathematics courses, students are trained to make judgments of results from calculations and problem solving. Within courses in mathematical statistics, students are trained to detect pitfalls within statistical analysis and evaluate statistical significance in data analysis.

In the course Mathematics, Science and Society, students are allowed to review and evaluate reports and evidence based on statistical surveys that underpin political decisions. In this course, students also gain insight into how, for example, SCB works. They may also review and evaluate ethical aspects of development in technology, data management and artificial intelligence.

Quality Development

The programme coordinator has the overall responsibility for the programme and the contact with the students.
The students are involved both in programme evaluations and course evaluations. The programme director regularly meets students to discuss courses and assist in the choice of optional courses. Compilations of course evaluations and programme evaluations will be archived by the department.

Degree Certificate

After completing programme studies, corresponding to the requirements expressed in the Higher Education Ordinance (Degree Ordinance) as well as the Linnaeus University

local Degree Ordinance, the student may apply for a degree. Students who have completed the Applied Mathematics Programme can obtain the following degrees:

Filosofie kandidatexamen med inriktning mot Matematik alt. Teknisk matematik alt. Datavetenskap och statistik alt. Ekonomi och operationsanalys
Huvudområde: Matematik

Bachelor of Science in Mathematics with specialization in Mathematics, or Engineering Mathematics, or Computer Science and Statistics, or Economics and Operations Research.
Main field of study: Mathematics
The degree certificate is bilingual (Swedish/English). The Degree Certificate is accompanied by a Diploma Supplement (English).

Other Information

The programme can be completely studied in English.
Some optional courses are given in Swedish only.