Faculty of Mathematics and Physics

STUDY GUIDE
2014/2015

Bachelor and Master Programmes
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Table of Contents
Dear Student,

Welcome to the Faculty of Mathematics and Physics at Charles University in Prague. Our faculty offers bachelor’s, master’s and doctoral degree programmes, given in either Czech or English. This document is dedicated to the bachelor’s and master’s programmes in English, namely to those leading to

- Bachelor of Computer Science
- Master of Computer Science
- Master of Mathematics.

In this introduction we provide the basic information you will need in order to study at our faculty. For supplementary information we refer to the Code of Study and Examination of Charles University in Prague and to the Rules for Organization of Studies at the Faculty of Mathematics and Physics. The subsequent chapters of this document describe the academic calendar for 2014/15 and the curricula for our programmes.

Academic Life

Duration of Study

The standard period of study for a bachelor’s programme is three years and for a master’s programme two years. The standard period of study for a degree programme is the period of time in which it is possible to successfully finish the respective degree programme if one follows the recommended course of study. The course of study is concluded with a state final examination and its successful completion leads to the degree of Bachelor of Computer Science (Bc.) for a bachelor’s degree programme and to the degree of Master of Computer Science or Master of Mathematics (Mgr.) in a master’s degree programme. The maximum period of study in a bachelor’s degree programme is six years and in a master’s degree programme five years.

Study Sections

Each academic year consists of a winter (October – January) and a summer (February – June) semester. In each semester there are typically 13 weeks of teaching and an examination period of 5 weeks. A study programme is subdivided into sections so that progress and compliance with the conditions for registration for the next study section can be regularly monitored; a study section is typically an academic year, although for students enrolling in 2014 in a bachelor’s programme, the first two study sections correspond to semesters (i.e., the first study section is the winter semester and the second study section is the summer semester). At the end of each study section there
is an Annual Evaluation of Study, whose purpose is to establish whether the results of your study hitherto qualify you to register for the next study section. (For those in their first year of a bachelor’s programme, the Annual Evaluation comes in two parts, one for each semester.) You are entitled to register for the first study section if you have successfully completed the admissions process. You are entitled to register for later study sections if you meet the requirements of the Annual Evaluation (see below). Registration is a confirmation that you are continuing your study at the faculty.

Degree Plan

Study in a degree programme is guided by a degree plan. A degree programme is divided into study branches and possibly further divided into specializations. The degree plan specifies the following for each degree programme, for each study branch and, where applicable, for each specialization:

- **Obligatory courses** (you have to complete these before the state final examination),
- **Elective courses** (you have to complete the prescribed part of these before the state final examination),
- **State final examination** - its parts and requisite knowledge needed for them,
- **Recommended course of study** (for some programmes) - assignment of obligatory and some elective courses to specific study sections; in some cases also provision of supplementary information on the curriculum.

The recommended course of study is not binding. However it is advisable to follow it because it is put together to satisfy the requisites (see below), considers the relationships between the courses, takes into account the schedule, and leads to timely graduation. All courses other than the obligatory and elective that are offered at the university are considered as **Optional courses** for the corresponding curriculum; it is up to you whether you decide to take some of these.

In all tables, obligatory courses are printed in **boldface**, elective courses are printed upright, and optional courses in **italics**. Here is a small example:

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPRG030</td>
<td>Programming I</td>
<td>6</td>
<td>3/2 C</td>
<td>—</td>
</tr>
<tr>
<td>NDMA012</td>
<td>Combinatorics and Graph Theory II</td>
<td>6</td>
<td>2/2 C+Ex</td>
<td>—</td>
</tr>
<tr>
<td>NMAI069</td>
<td>Mathematical skills</td>
<td>2</td>
<td>0/2 C</td>
<td>—</td>
</tr>
</tbody>
</table>

The course code is given in the first column. The number in the “Credit” column specifies the number of ECTS credits for completion of the course. The Winter and Summer columns specify the semester in which the course is offered, the number of hours of lectures/ hours of classes per week, and how the course is assessed (i.e., by a course credit – C, by an exam – Ex).

Course Enrolment

At the beginning of each semester there is a period of several weeks during which you should choose and then enrol in courses that you plan to take that semester (see Academic Calendar). Enrolment is performed electronically through the Student Information System (SIS) – [http://www.mff.cuni.cz/sis](http://www.mff.cuni.cz/sis). It is up to you which courses to enrol in, subject to the requirements of your curriculum and to the number of credits
Introduction

required in the Annual Evaluation. If your interests are wider than specified by your curriculum or if you decide not to follow the recommended course of study exactly, then you can enrol in additional courses; there is no upper limit to the number of courses in which you can enrol. Course enrolment may be restricted by certain conditions (requisites), of which the most common are the following:

- **Prerequisite** – A prerequisite to Course X is a course that must be successfully completed before you can enrol in Course X.

- **Corequisite** – A corequisite to Course X is a course that you have to enrol in at the same time as Course X, or that you have already successfully completed.

- **Prohibited combination** (or incompatibility) – Courses X and Y are a prohibited combination if it is impossible to enrol in Course X when you have already completed, or you enrol in, Course Y.

In some cases, it is specified that completion of Course Y is equivalent, with respect to the requirements of the curriculum, to completion of Course X; these two courses are called equivalent or interchangeable. Information about these relationships among courses are described in the Student Information System in the module “Subjects” (http://www.mff.cuni.cz/courses) and in the List of Courses of the Faculty of Mathematics and Physics (electronic edition). Please note that the prerequisites and corequisites for a course X, as specified in SIS and in the List of Courses, apply to study programmes and study branches in which the course is compulsory or elective. We recommend giving due attention to these conditions, as missing a course that is a prerequisite for another course in which you intend to enrol may result in an unfavourable extension of period of study.

Lectures and Classes

Courses are mostly given in the form of lectures and/or classes. A lecture is an oral presentation intended to teach students a particular subject. Typically accompanying a series of lectures are classes, in which a tutor helps a small group of students assimilate material from lectures and is able to give students individual attention. Classes for programming-related courses typically take place in computer labs. The schedule of the faculty is given as 45-minute periods with 5-minute breaks, and most lectures and classes are organized as 90-minute long blocks of two such periods, taking place once or twice a week. Attendance of lectures and classes is usually not required, but is strongly recommended. Information about course locations and times is available in the Student Information System in the module “Schedule” (http://www.mff.cuni.cz/schedule). Lectures are mostly given by senior faculty members, whose academic ranks are professor (in Czech profesor) or associate professor (docent). Classes are usually conducted by junior researchers and Ph.D. students. Apart from lectures and classes, another significant component of a student’s timetable is private study.

Exams and Course Credits

Mastery of a course is confirmed by a course credit and/or by an exam. A course credit (usually for classes) is awarded at the end of the semester. The conditions for obtaining a course credit differ according to the nature of the course, for example involving the completion of a test, programming an application, or writing a survey. The possible outcomes are Pass (in Czech Započteno) and Fail. Exams are taken
during the examination period at the end of the semester and may be oral, written, or a combination of the two. Examination dates are announced by the lecturer at the beginning of the examination period. There are four possible outcomes for an exam (the corresponding numerical values and Czech equivalents are given in parentheses): Excellent (1 - Výborně), Very good (2 - Velmi dobře), Good (3 - Dobře), Fail (4 - Nepřehověl). You pass an exam if you obtain a grade of Excellent, Very good or Good; otherwise you fail. You have up to three attempts to pass an exam (provided there are still dates available) but we strongly recommend preparing as well as you can for the first attempt. If you do not succeed in passing the exam for a course, you are allowed to take the course again in the next section of study, but a course can be followed at most twice. For each successfully completed course you obtain a certain number of ECTS credits that is specified for each subject in the curriculum (and also given in SIS and the List of Courses of the Faculty of Mathematics and Physics).

**Annual Evaluation of Study**

Progress is monitored at the end of each study section. The Annual Evaluation of Study involves a check of your credit total, that is, the number of credits received for your completed study sections. If you have attained in previous study sections in total at least the normal number of credits (corresponding to the sum of the credits in these sections in the recommended course of study), or if you have obtained at least the minimum number of credits (see below), then you have the right to enrol in the next study section. If you have not received the minimum number of credits, then this is considered as a failure to fulfil the requirements of the study programme and results in exclusion. The normal and minimum numbers of credits required for registration in the next study section are given as follows (normal number of credits is followed in parentheses by minimum number of credits):

- **Normal and minimum number of credits**
  - **Bachelor’s degree programmes - for students enrolled first in 2014/15**
    - 30 (15) for enrolment to the second study section (i.e., the summer semester of the first year of study),
    - 60 (45) for enrolment to the third study section (i.e., the second year),
    - 120 (90) for enrolment to the fourth study section (i.e., the third year),
    - 180 (135) for enrolment to the fifth study section (i.e., the fourth year),
    - 240 (180) for enrolment to the sixth study section (i.e., the fifth year),
    - 300 (225) for enrolment to the seventh study section (i.e., the sixth year).
  - **Bachelor’s degree programmes - for students enrolled before 2014/15**
    - 60 (45) for enrolment to the second study section (i.e., the second year),
    - 120 (90) for enrolment to the third study section (i.e., the third year),
    - 180 (135) for enrolment to the fourth study section (i.e., the fourth year),
    - 240 (180) for enrolment to the fifth study section (i.e., the fifth year),
    - 300 (225) for enrolment to the sixth study section (i.e., the sixth year).
  - **Master’s degree programmes - for all students**
    - 60 (45) for enrolment to the second study section (i.e., the second year),
    - 120 (90) for enrolment to the third study section (i.e., the third year),
    - 180 (135) for enrolment to the fourth study section (i.e., the fourth year),
    - 240 (180) for enrolment to the fifth section study (i.e., the fifth year).
Introduction

For the purpose of the Annual Evaluation of Study, all the credits for completed compulsory and elective courses are counted, and credits for optional courses are counted up to the following limits (in parentheses we specify to what percentage of the corresponding normal number of credits the maximum number corresponds):

- **Maximum number of credits for optional courses**
  
  **Bachelor’s degree programmes - for students enrolled first in 2014/15**
  - 4 credits (15 %) for enrolment to the second study section,
  - 9 credits (15 %) for enrolment to the third study section,
  - 18 credits (15 %) for enrolment to the fourth study section,
  - 54 credits (30 %) for enrolment to the fifth study section,
  - 72 credits (30 %) for enrolment to the sixth study section,
  - 90 credits (30 %) for enrolment to the seventh study section.

  **Bachelor’s degree programmes - for students enrolled before 2014/15**
  - 9 credits (15 %) for enrolment to the second study section,
  - 26 credits (22 %) for enrolment to the third study section,
  - 86 credits (48 %) for enrolment to the fourth study section,
  - 146 credits (61 %) for enrolment to the fifth study section,
  - 204 credits (68 %) for enrolment to the sixth study section.

  **Master’s degree programmes - for students enrolled first in 2014/15**
  - 18 credits (30 %) for enrolment to the second study section,
  - 60 credits (50 %) for enrolment to the third study section,
  - 126 credits (70 %) for enrolment to the fourth study section,
  - 167 credits (70 %) for enrolment to the fifth section study.

  **Master’s degree programmes - for students enrolled before 2014/15**
  - 30 credits (50 %) for enrolment to the second study section,
  - 60 credits (50 %) for enrolment to the third study section,
  - 180 credits (100 %) for enrolment to the fourth study section,
  - 240 credits (100 %) for enrolment to the fifth section study.

You are allowed to enrol in and complete optional courses with a larger number of credits than the maximum specified above, but then some of these credits will not be considered in the Annual Evaluation of Study. Although you technically only need the minimum number of credits to register for the next study section, we strongly recommend attaining the normal number of credits, otherwise you most likely will not be able to complete your study programme within the standard period of time.

**State Final Exam**

Study is concluded with a state final examination. This examination consists of several parts (two or three, depending on the corresponding curriculum), one of which for bachelor’s degree programmes is always the defence of a bachelor’s thesis and for master’s degree programmes the defence of a master’s (diploma) thesis. If a student fails a part of the state final exam, only the failed part is repeated. Each part of the state final exam may be repeated at most twice. Each part of the state final exam is graded separately and from these an overall grade is awarded.

A necessary condition for taking the state final examination is in bachelor’s degree programmes the acquisition of at least 180 credits and in master’s degree programmes at least 120 credits. The knowledge requirements for the state exam are specified in
the degree plans of the respective study programmes and branches of study, and are described in detail in the following chapters of this document.

Some Suggestions

Advising others is always a bit tricky but nevertheless I would like to give here a few suggestions for making the most of your time at our faculty. They are addressed primarily to students in their first year.

Ask questions. As the wise old saying goes, “Many things are lost for want of asking.” Please do not hesitate to ask when you do not understand something – in our culture it is not considered impolite or improper to do so. Ask the lecturer during the lecture or after, ask the tutor during the class or after it, ask your classmates who (think that they) understand. Arrange a meeting with your teacher during office hours and ask there.

Write. Many of you will learn faster and better if listening and reading is complemented by writing. These days, for many courses there are excellent written materials, often including slides prepared by the lecturer. Nevertheless, many of you will profit by taking your own notes at lectures and classes. It is important to use pen and paper during your preparation for tests and exams. Do you think that you already understand the proof of a theorem? Write it down with the book closed, making sure to include all necessary details. Finally, if you want to learn to program well, write some code.

Work. Even if nobody makes you do so. In contrast to many secondary schools, you will not have to take a test or do homework every day. However, there will be plenty of tests and exams at the end of the semester. Be aware of that and learn as much as you can during the semester rather than later. You will learn more, you will retain it longer, and the examination period will go more smoothly for you.

Plan. This is related to the previous point. In the examination period you will rarely be able to learn well for an exam during a single day or night. Take this into account when planning the dates of your exams in the examination period. Allow yourself enough time to prepare for exams, to code programs or to solve problems for obtaining a course credit. Reserve some time for possible second attempts at failed exams. Do not postpone until the next semester or the next year what you are to do now. If you do so, most likely you will not be able to catch up.

Think. Not everything that you read on the internet is correct. Not even everything that you hear in a lecture is always correct (we all make mistakes). Try to understand everything. Do not be content merely with answers to the questions how? and what?, but also ask why? If you have a question, try first to find an answer by yourself before searching for an answer in a textbook or on the internet.

Best wishes for an enjoyable and successful academic year,

Petr Kolman
Vice Dean for Education
Academic calendar

Sep 1 – Sep 14, 2014  Autumn period for bachelor’s state final examinations
Sep 8 – Sep 21, 2014  Autumn period for master’s state final examinations
Sep 15 – Sep 30, 2014  Electronic enrolment in winter semester courses – priority mode
until Sep 30, 2014  Annual evaluation for academic year 2013/2014 and registration for second and higher years of bachelor’s and master’s programmes
Oct 1, 2014  Beginning of academic year 2014/2015 and of its winter semester
Oct 1 – Oct 19, 2014  Electronic enrolment in winter semester courses – open mode
Oct 1, 2014 – Jan 9, 2015  Winter semester tuition
Oct 20 – Oct 31, 2014  Approval of electronic enrolment in courses by the Department of Student Affairs
Nov 6, 2014  Matriculation of first year students on bachelor’s and master’s study programmes
until Nov 7, 2014  Recommended period for deciding bachelor’s thesis topics
Nov 12, 2014  Dean’s Sports Day (no lectures or classes)
Nov 12 – Nov 14, 2014  Graduation Ceremony – bachelor’s study programmes
Nov 26, 2014  Open Day
until Dec 5, 2014  Submission of bachelor’s and master’s (diploma) thesis for winter period of state final examinations
Dec 11, 2014  Graduation Ceremony – master’s study programmes
Dec 22, 2014 – Jan 4, 2015  Christmas vacation
Jan 12 – Feb 15, 2015  Winter semester examination period
until Jan 16, 2015  Registration for winter period of master’s and bachelor’s state final examinations
Winter sports training course – details given by Department of Physical Education
Jan 26 – Feb 8, 2015  Winter period for bachelor’s and master’s state final examinations
Feb 2 – Feb 15, 2015  Electronic enrolment in summer semester courses – priority mode
<table>
<thead>
<tr>
<th>Date Range</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 16 – Mar 8, 2015</td>
<td>Electronic enrolment in summer semester courses – open mode</td>
</tr>
<tr>
<td></td>
<td>For first year bachelor’s students extended till Apr 8, 2015</td>
</tr>
<tr>
<td>Feb 16, 2015</td>
<td>Beginning of summer semester of academic year 2014/2015</td>
</tr>
<tr>
<td>Feb 16 – May 22, 2015</td>
<td>Summer semester tuition</td>
</tr>
<tr>
<td></td>
<td>until Feb 20, 2015 Recommended period for deciding master’s thesis topics</td>
</tr>
<tr>
<td>Mar 9 – Mar 20, 2015</td>
<td>Approval of electronic enrolment in courses by the</td>
</tr>
<tr>
<td></td>
<td>Department of Student Affairs</td>
</tr>
<tr>
<td></td>
<td>until May 7, 2015 Registration for summer period of master’s state final examinations</td>
</tr>
<tr>
<td></td>
<td>Submission of master’s thesis for summer period of state final examinations</td>
</tr>
<tr>
<td>May 13, 2015</td>
<td>Rector’s Day (no lectures or classes)</td>
</tr>
<tr>
<td></td>
<td>until May 22, 2015 A. Registration for summer period of bachelor’s state final examinations</td>
</tr>
<tr>
<td></td>
<td>B. Submission of bachelor’s thesis for summer period of state final examinations</td>
</tr>
<tr>
<td>May 25 – Jun 30, 2015</td>
<td>Summer semester examination period</td>
</tr>
<tr>
<td>Jun 3 – Jun 16, 2015</td>
<td>Summer period for master’s state final examinations</td>
</tr>
<tr>
<td>Jun 11 – Jun 16, 2015</td>
<td>Entrance Examinations – bachelor’s and master’s study programmes</td>
</tr>
<tr>
<td>Jun 15 – Jun 28, 2015</td>
<td>Summer period for bachelor’s state final examinations</td>
</tr>
<tr>
<td></td>
<td>Summer sports training course – details given by Department of Physical Education</td>
</tr>
<tr>
<td>Jul 1 – Aug 31, 2015</td>
<td>Summer vacation</td>
</tr>
<tr>
<td>Jul 10, 2015</td>
<td>Graduation Ceremony – master’s study programmes</td>
</tr>
<tr>
<td></td>
<td>until Jul 31, 2015 A. Submission of master’s (diploma) and</td>
</tr>
<tr>
<td></td>
<td>bachelor’s thesis for autumn period of state final examinations</td>
</tr>
<tr>
<td></td>
<td>B. Registration for autumn period of master’s and</td>
</tr>
<tr>
<td></td>
<td>bachelor’s state final examinations</td>
</tr>
<tr>
<td>Sep 1 – Sep 14, 2015</td>
<td>Autumn period for bachelor’s state final examinations</td>
</tr>
<tr>
<td>Sep 7 – Sep 20, 2015</td>
<td>Autumn period for master’s state final examinations</td>
</tr>
<tr>
<td></td>
<td>until Sep 30, 2015 Annual evaluation for academic year 2014/2015 and registration</td>
</tr>
<tr>
<td></td>
<td>for second and higher years of bachelor’s and master’s study programmes</td>
</tr>
<tr>
<td>Sep 30, 2015</td>
<td>End of academic year 2014/2015</td>
</tr>
</tbody>
</table>
Location of faculty buildings

The Faculty of Mathematics and Physics comprises the School of Mathematics, the School of Physics, and the School of Computer Science. The schools are based at several locations in Prague. Here we provide basic information about their locations and about lecture rooms in the corresponding buildings. More details about the internal structure of the Faculty of Mathematics and Physics are given at http://www.mff.cuni.cz/to.en/fakulta/struktura/, and more details about locations and directions for faculty buildings are given at http://www.mff.cuni.cz/to.en/fakulta/budovy/.

School of Mathematics

Address: Sokolovská 83, 186 00 Praha 8

Lecture rooms
   K1, K2, K3, K4, K5, K6, K7, K8, K9, K11, K12

Computer labs
   K10

School of Computer Science

Address: Malostranské nám. 25, 118 00 Praha 1

Lecture rooms
   S1, S3, S4, S5, S6, S7, S8, S9, S10, S11

Computer labs
   SW1, SW2
School of Physics

The School of Physics is based in two locations: V Holešoviškách and Ke Karlovu.

Address: V Holešovičkách 2, 180 00 Praha 8

Lecture rooms
   T1, T2, T5, T6, T7, T8, T9, T10, T11

Computer labs
   LabTF, LabTS

There are two neighbouring faculty buildings in the street Ke Karlovu.

Address: Ke Karlovu 3, 121 16 Praha 2

Lecture rooms
   M1, M2, M3, M5, M6

Computer labs
   PLK

Address: Ke Karlovu 5, 121 16 Praha 2

Lecture rooms
   F1, F2

Charles University Sports Centre

Address: Bruslařská 10, 102 00 Praha 10
Administration

Charles University in Prague

Address: Ovocný trh 5, 116 36 Praha 1

Rector: prof. MUDr. Tomáš Zima, DrSc., MBA

Faculty of Mathematics and Physics

Address: Ke Karlovu 3, 121 16 Praha 2, phone 221 911 289, fax 221 911 292, e-mail: sdek@dekanat.mff.cuni.cz

Dean

prof. RNDr. Jan Kratochvíl, CSc.

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Vice Dean for Public Relations: RNDr. Martin Vlach, Ph.D.
Secretary: Ing. Antonín Líška
Master of Mathematics

1 General Information

Programme coordinator: doc. Mgr. Petr Kaplický, Ph.D.

The study programme Master of Mathematics consists of the following study branches:

- Mathematical Structures
- Mathematical Methods of Information Security
- Mathematical Analysis
- Numerical and Computational Mathematics
- Mathematical Modelling in Physics and Technology
- Probability, Mathematical Statistics and Econometrics
- Financial and Insurance Mathematics

Assumed knowledge

Individual branches have specific entry requirements for the knowledge assumed to have been already acquired before the start of the Master’s programme. Upon evaluation of the previous study experience of each incoming student, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

State Final Exam

Study in the master’s programme is completed by passing the state final exam. It consists of two parts: defence of the master’s (diploma) thesis, and an oral examination. Requirements for the oral part of the state final exam are listed in the following sections.

Students are advised to select the topic of their master’s (diploma) thesis during the first year of the study. Work on the master’s thesis is recognized by credits awarded upon taking the following courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSZZ023</td>
<td>Diploma Thesis I</td>
<td>6</td>
<td>0/4 C</td>
<td>0/4 C</td>
</tr>
<tr>
<td>NSZZ024</td>
<td>Diploma Thesis II</td>
<td>9</td>
<td>0/6 C</td>
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<td>15</td>
<td>0/10 C</td>
<td>0/10 C</td>
</tr>
</tbody>
</table>

A student should enrol in these courses according to instructions of their thesis advisor (after the thesis topic has been assigned). These courses can be taken between the second semester of the first year and the last semester of study, in an arbitrary order and in an arbitrary semester. The credits for these courses are assigned by the thesis advisor. The last credits for these courses should be awarded when the master’s thesis has been almost completed.
The deadlines for the assignment of the master’s thesis topic, submission of the completed thesis, and enrolment in the final exam are determined by the academic calendar.

Project

A student can request an assignment of a project from the dean. The number of credits earned upon completion of the project (max. 9) is specified by the dean on the recommendation of the project advisor and the coordinator of the study programme.

2 Degree Plans - Mathematical Structures

Coordinated by: Department of Algebra

Study branch coordinator: prof. RNDr. Jan Krajíček, DrSc.

The curriculum is focused on extending general mathematical background (algebraic geometry and topology, Riemann geometry, universal algebra and model theory) and obtaining deeper knowledge in selected topics of algebra, geometry, logic, and combinatorics. The aim is to provide sufficient general knowledge of modern structural mathematics and to bring students up to the threshold of independent research activity. Emphasis is laid on topics taught by instructors who have achieved worldwide recognition in their field of research.

A graduate has advanced knowledge in algebra, geometry, combinatorics and logic. He/she is in close contact with the latest results of contemporary research in the selected field. The abstract approach, extensiveness and intensiveness of the programme result in the development of the ability to analyse, structure and solve complex and difficult problems. Graduates may pursue an academic career or realize themselves in jobs that involve mastering new knowledge and control of complex systems.

Assumed knowledge

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Linear algebra, real and complex analysis, and probability theory.
- Foundations of group theory (Sylow theorems, free groups, nilpotence). Lie groups, analysis on manifolds, ring and module theory (finiteness conditions, projective and injective modules), commutative algebra (Galois theory, integral extensions).
- Intermediate knowledge of mathematical logic (propositional and first order logic, incompleteness and undecidability).

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

2.1 Obligatory courses

<table>
<thead>
<tr>
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<th>Subject</th>
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<th>Summer</th>
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### Mathematical Structures

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#### 2.2 Elective Courses

It is required to earn at least 35 credits from the following elective courses.

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<td>NMAG433</td>
<td>Riemann Surfaces</td>
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<td>NMAG434</td>
<td>Categories of Modules and Homological Algebra</td>
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<td>NMAG435</td>
<td>Lattice Theory 1</td>
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<td>NMAG437</td>
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<td>Group Representations 1</td>
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<td>Binary Systems</td>
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<tr>
<td>NMAG442</td>
<td>Representation Theory of Finite-Dimensional Algebras</td>
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<td>NTIN022</td>
<td>Probabilistic Method</td>
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</table>
2.3 State Final Exam

Requirements for taking the final exam

- Earning at least 120 credits during the course of the study.
- Completion of all obligatory courses prescribed by the study plan.
- Earning at least 35 credits by completion of elective courses.
- Submission of a completed Master’s Thesis by the submission deadline.

Oral part of the state final exam

The oral part of the final exam consists of a common subject area “1. Mathematical Structures” and a choice of one of four subject areas “2A. Geometry”, “2B. Representation Theory”, “2C. General and Combinatorial Algebra”, or “2D. Combinatorics”. One question is asked from subject area 1 and one question is asked from the subject area selected from among 2A, 2B, 2C, or 2D.

Requirements for the oral part of the final exam

Common requirements

1. Mathematical Structures

Basics of algebraic geometry, universal algebra, Riemannian geometry, algebraic topology, model theory and combinatorics.

Specialization

2A. Geometry

Harmonic analysis and invariants of classical groups, Riemannian surfaces, algebraic topology, fibre spaces and covariant derivation.

2B. Representation Theory

Representations of groups, representations of finite-dimensional algebras, combinatorial group theory, curves and function fields, and homological algebra.

2C. General and Combinatorial Algebra

Finite groups and their representations, combinatorial group theory, binary systems (semigroups, quasigroups), advanced universal algebra (lattices, clones, Malcev conditions), complexity and enumerability, undecidability in algebraic systems.

2D. Combinatorics

Applications of linear algebra, combinatorics and graph theory, application of probabilistic method in combinatorics and graph theory, analytic and combinatorial number theory, combinatorial and computational geometry, structural and algorithmic graph theory.

2.4 Recommended Course of Study

1st year

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
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<tbody>
<tr>
<td>NMAG401</td>
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<td>Combinatorics</td>
<td>5</td>
<td>2/2 C+Ex</td>
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</tbody>
</table>
This programme is focused on deepening the theoretical knowledge of mathematical subjects relevant to the field and their algorithmic understanding. Among the subjects studied are number theory, probability theory, theory of error-correcting codes, complexity theory, theory of elliptic curves, and computer algebra applied to some of these subjects. Attention is also given to practical aspects such as internet security, standards in cryptography, and legal aspects of data security. Cryptoanalytic attacks are the topic of one course but are also covered by other courses and frequently arise among topics of seminar projects and diploma theses.

A graduate will be acquainted with current data protection and security systems, their mathematical principles, practical use, and commonly used protocols. His/her mathematical knowledge will fully cover the theoretical foundations of cryptography (number theory, error-correcting codes, complexity theory, theory of elliptic curves). He/she will be familiar with standards in cryptography and legal aspects of data security. He/she will be able to hold positions in institutions and companies utilizing concepts of data security and authentication. An academic career will also be possible.

Assumed knowledge

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Linear algebra, real and complex analysis, and probability theory.
- Foundations of commutative and computer algebra (Galois theory, integral extensions, discrete Fourier transformation), modular arithmetic, multiplicative groups, finite fields, basic classes of error-correcting codes, and the group operations on elliptic curves.
- Basics of theoretic and applied cryptography (symmetric and public-key cryptography, differential and linear cryptanalysis). Programming in C.
Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

### 3.1 Obligatory Courses

<table>
<thead>
<tr>
<th>Code</th>
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### 3.2 Elective Courses

#### Set 1

It is required to earn at least 21 credits from this group.

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<td>NMAG003</td>
<td>Authentication Schemes</td>
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<td>3</td>
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<td>Legal Aspects of Data Protection</td>
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<td>NMAG006</td>
<td>Number Field Sieve</td>
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<td>Standards and Cryptography</td>
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<td>Elliptic Curves and Cryptography</td>
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#### Set 2

It is required to earn at least 5 credits from this group.

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<td>Geometric Modelling</td>
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<td>Fundamentals of Continuous Optimization</td>
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<td>Introduction to Mathematical Modelling</td>
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### 3.3 State Final Exam

**Requirements for taking the final exam**

- Earning at least 120 credits during the course of the study.
- Completion of all obligatory courses prescribed by the study plan.
- Earning at least 21 credits by completion of elective courses from group I.
- Earning at least 5 credits by completion of elective courses from group II.
- Earning at least 6 credits by completion of elective courses from group III.
- Submission of a completed Master’s Thesis by the submission deadline.

**Oral part of the state final exam**

The oral part of the final exam consists of three subject areas: “Algebraic Foundations of Cryptography”, “Coding and Cryptologic Algorithms”, and “Complexity and Probability”. One question is asked from each subject area.

**Requirements for the oral part of the final exam**

1. **Algebraic foundations of cryptography**


2. **Coding and cryptologic algorithms**

   Numerical algorithms, algorithms for computing with polynomials and another important algorithms used in cryptography and cryptanalysis. Iterative coding methods.

3. **Complexity and probability**

   Deterministic, non-deterministic and probabilistic models of computation and their complexity, randomness and pseudo-randomness, and information geometry.
3.4 Recommended Course of Study

1st year

<table>
<thead>
<tr>
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Optional and Elective Courses

2nd year

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</table>

Optional and Elective Courses

31

4 Degree Plans - Mathematical Analysis

Coordinated by: Department of Mathematical Analysis

Study branch coordinator: doc. RNDr. Ondřej Kalenda, Ph.D., DSc.

The mathematical analysis curriculum offers advanced knowledge of fields traditionally forming mathematical analysis (real function theory, complex analysis, functional analysis, ordinary and partial differential equations). It is characterized by a depth of insight into individual topics and emphasis on their mutual relations and interconnections. Advanced knowledge of these topics is provided by a set of obligatory courses. Elective courses deepen the knowledge of selected fields, especially those related to the diploma thesis topic. Seminars provide contact with contemporary mathematical research. Mathematical analysis has close relationships with other mathematical disciplines, such as probability theory, numerical analysis and mathematical modelling. Students become familiar with these relationships in some of the elective courses. The programme prepares students for doctoral studies in mathematical analysis and related subjects. Applications of mathematical theory, theorems and methods to applied problems broaden the qualification to employment in a non-research environment.

The graduate will acquire advanced knowledge in principal fields of mathematical analysis (real function theory, complex analysis, functional analysis, ordinary and partial differential equations), understand their interconnections and relations to other mathematical disciplines. He/she will be able to apply advanced theoretical methods to real problems. The programme prepares students for doctoral studies but the knowledge and abilities acquired can be put into use in practical occupations as well.
**Assumed knowledge**

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Differential calculus of one and several real variables. Integral calculus of one real variable. Measure theory, Lebesgue measure and Lebesgue integral. Basic algebra (matrix calculus, vector spaces).
- Foundations of general topology (metric and topological spaces, completeness and compactness), complex analysis (Cauchy integral theorem, residue theorem, conformal maps, Laplace transform) and functional analysis (Banach and Hilbert spaces, dual spaces, bounded operators, compact operators, basic theory of distributions).

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

### 4.1 Obligatory Courses

<table>
<thead>
<tr>
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<th>Summer</th>
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### 4.2 Elective Courses

**Set 1**

The courses in this group introduce various research areas in mathematical analysis, illustrate their applications, and cover other fields that are related to mathematical analysis. It is required to earn at least 12 credits from this group.

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### Master of Mathematics

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</table>

### Set 2

This group includes scientific seminars and workshops. It is required to earn at least 12 credits from this group. Each semester yields 3 credits and the seminars can be taken repeatedly.

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4.3 State Final Exam

Requirements for taking the final exam

– Earning at least 120 credits during the course of the study.
– Completion of all obligatory courses prescribed by the study plan.
– Earning at least 12 credits by completion of elective courses from group I.
– Earning at least 12 credits by completion of elective courses from group II.
– Submission of a completed master’s thesis by the submission deadline.

Oral part of the state final exam

The oral part of the final exam consists of five subject areas: “Real Analysis”, “Complex Analysis”, “Functional Analysis”, “Ordinary Differential Equations”, and “Partial Differential Equations”. One question is asked from each subject area.

Requirements for the oral part of the final exam

1. Real Analysis

Measure theory and signed measures, Radon measures. Absolutely continuous functions and functions with bounded variation. Hausdorff measure and Hausdorff dimension. Elements of descriptive set theory.

2. Complex Analysis


3. Functional Analysis


4. Ordinary Differential Equations


5. Partial Differential Equations

Linear and quasilinear first order equations. Linear and nonlinear elliptic equations. Linear and nonlinear parabolic equations. Linear hyperbolic equations. Sobolev and Bochner spaces.

4.4 Recommended Course of Study

1st year

<table>
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<tr>
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<td>Functional Analysis 2</td>
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<td>3/1 C+Ex</td>
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</table>
This programme focuses on design, analysis, algorithmization, and implementation of methods for computer processing of mathematical models. It represents a transition from theoretical mathematics to practically useful results. An emphasis is placed on the creative use of information technology and production of programming applications. An integral part of the programme is the verification of employed methods. The students will study modern methods for solving partial differential equations, the finite element method, linear and non-linear functional analysis, and methods for matrix calculation. They will choose the elective courses according to the topic of their master’s thesis. They can specialise in industrial mathematics, numerical analysis, or matrix calculations.

The graduate will have attained the knowledge needed for numerical solution of practical problems from discretization through numerical analysis up to implementation and verification. He/she can will be able to choose an appropriate numerical method for a given problem, conduct its numerical analysis, and implement its computation including analysis of numerical error. The graduate will be able to critically examine, assess, and tune the whole process of the numerical solution, and can assess the agreement between the numerical results and reality. He/she will be able to carry out an analytical approach to the solution of a general problem based on thorough and rigorous reasoning. The graduate will be qualified for doctoral studies and for employment in industry, basic or applied research, or government institutions.

**Assumed knowledge**

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Foundations of functional analysis (Banach and Hilbert spaces, duals, bounded operators, compact operators, basics of the theory of distributions), theory of ordinary differential equations (basic properties of the solution and maximal solutions, systems of linear equations, stability) and partial differential equations (quasilinear equations of first order, Laplace equation, heat equation and wave equation).

- Foundations of numerical mathematics (numerical quadrature, basics of the numerical solution of ordinary differential equations, finite difference method for partial differential equations) and of analysis of matrix computations (Schur theorem, orthogonal transformations, matrix decompositions, basic iterative methods).

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

### 5.1 Obligatory Courses

<table>
<thead>
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### 5.2 Elective Courses

It is required to earn at least 28 credits from elective courses. The selection of elective courses should take into account the planned choice of the third subject area for the final exam. The subject area for which the course is recommended is shown in parentheses (3A, 3B or 3C). The course NMNV451 Seminar in Numerical Mathematics can be taken repeatedly. We recommend enrolling in it for each semester of study.

<table>
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5.3 State Final Exam

Requirements for taking the final exam

– Earning at least 120 credits during the course of the study.
– Completion of all obligatory courses prescribed by the study plan.
– Earning at least 28 credits by completion of elective courses.
– Submission of a completed master’s thesis by the submission deadline.

Oral part of the state final exam

The oral part of the final exam consists of two common subject areas “1. Mathematical and Functional Analysis” and “2. Numerical Methods” and a choice of one of three subject areas “3A. Industrial Mathematics”, “3B. Numerical Analysis”, or “3C. Matrix Computations”. One question is asked from subject areas 1 and 2 and one question is asked from the subject area selected from among 3A, 3B, or 3C.

Requirements for the oral part of the final exam

1. Mathematical and functional analysis

   Partial differential equations, spectral analysis of linear operators, monotone and potential operators, solution of variational problems

2. Numerical methods

   Finite element method, basic matrix iterative methods, methods for the solution of systems of nonlinear algebraic equations, basics of the implementation of numerical methods

3. Choice of one of the following topics:

   3A. Industrial Mathematics

   Mathematical methods in fluid mechanics, methods of material optimization, methods of solution of evolutionary equations
3B. Numerical Analysis
Nonlinear differential equations, numerical methods for ordinary differential equations, numerical solution of convection-diffusion problems

3C. Matrix Computations
Methods of Krylov subspaces, projections and problem of moments, connection between spectral information and convergence, direct methods for sparse matrices

5.4 Recommended Course of Study

1st year

<table>
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<tr>
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Optional and Elective Courses

2nd year

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</table>

Optional and Elective Courses

6 Degree Plans - Mathematical Modelling in Physics and Technology

Coordinated by: Mathematical Institute of Charles University
Study branch coordinator: prof. RNDr. Josef Málek, CSc., DSc.

Mathematical modelling is an interdisciplinary field connecting mathematical analysis, numerical mathematics, and physics. The curriculum is designed to provide excellent basic knowledge in all these disciplines and to allow a flexible widening of knowledge by studying specialized literature when the need arises. All students take obligatory courses in continuum mechanics, partial differential equations, and numerical mathematics. Students will acquire the ability to design mathematical models of natural
phenomena (especially related to continuum mechanics and thermodynamics), analyse them, and conduct numerical simulations. After passing the obligatory classes, students get more closely involved with physical aspects of mathematical modelling (model design), with mathematical analysis of partial differential equations, or with methods for computing mathematical models. The grasp of all levels of mathematical modelling (model, analysis, simulations) allows the students to use modern results from all relevant fields to address problems in physics, technology, biology, and medicine that surpass the scope of the fields individually. Graduates will be able to pursue academic or commercial careers in applied mathematics, physics and technology.

The graduate will have mastered methods and results in continuum mechanics and thermodynamics, mathematical analysis of partial differential equations, and numerical mathematics, and will be ready to widen his/her knowledge by studying specialized literature. He/she will be able to formulate questions regarding the physical substance of natural phenomena, especially those related to the behaviour of fluids and solid matter in the framework of classical physics, with applications to technology, medicine, biology, geophysics, and meteorology. He/she will be able to choose appropriate mathematical models for such phenomena, carry out its mathematical analysis, and conduct numerical simulations with suitable methods. He/she will be able to critically analyse, evaluate, and tie in the whole modelling process. In simpler cases, he/she will be able to assess the errors in the modelling process and predict the agreement between numerical results and the physical process. The graduate will be ready to work in interdisciplinary teams. He/she will be able to pose interesting questions in a format ready for mathematical investigation and use abstract mathematical results in order to address applied problems.

**Assumed knowledge**

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- **Foundations of differential and integral calculus of one variable and several variables.** Volume, surface and line integral. Measure theory. Lebesgue integral.


- **Foundations of complex analysis** (Cauchy theorem, residual theorem, conformal mappings, Laplace transform).

- **Foundations of functional analysis and theory of metric spaces** (Banach and Hilbert spaces, operators and functionals, Hahn-Banach theorem, dual space, bounded operators, compact operators, theory of distributions).

• Foundations of classical mechanics (Newton laws, Lagrange equations, Hamilton equations, variational formulation, rigid body dynamics).

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

### 6.1 Obligatory Courses

<table>
<thead>
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<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
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### 6.2 Elective Courses

It is required to earn at least 16 credits from elective courses.

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### 6.3 State Final Exam

**Requirements for taking the final exam**

- Earning at least 120 credits during the course of the study.
- Completion of all obligatory courses prescribed by the study plan.
- Earning at least 16 credits by completion of elective courses.
- Submission of a completed master’s thesis by the submission deadline.

**Oral part of the state final exam**

The oral part of the final exam consists of three subject areas: “Continuum Mechanics and Thermodynamics”, “Functional Analysis and Partial Differential Equations”, and “Numerical Methods”. One question is asked from each subject area.

**Requirements for the oral part of the final exam**

1. **Continuum mechanics and thermodynamics**

2. **Functional analysis and partial differential equations**

3. **Numerical methods**
6.4 Recommended Course of Study

### 1st year

<table>
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### Optional and Elective Courses

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### Optional and Elective Courses

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<td>0/10 C</td>
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### 7 Degree Plans - Probability, Mathematical Statistics and Econometrics

**Coordinated by:** Department of Probability and Mathematical Statistics  
**Study branch coordinator:** doc. RNDr. Daniel Hlubinka, Ph.D.

The curriculum is targeted at students who wish to obtain theoretical and practical knowledge about the mathematics of random events. It is primarily characterized by a balance between rigorous mathematical theory, depth of insight into various fields of the subject (probability, statistics, econometrics), and applications in various areas. The students will obtain a general background by taking compulsory courses in probability, optimization, linear regression and random processes. They continue by taking elective courses to extend their expertise and choose a specialization they wish to study more deeply. In seminars, they learn to work independently as well as to collaborate on complex projects. Great emphasis is placed on the development of independent analytical thinking. Probability, statistics and econometrics have a close relationship to other mathematical subjects (mathematical analysis, numerical mathematics, discrete mathematics). Applications are inspired by real problems from economics, medicine,
Master of Mathematics

technology, natural sciences, physics and computer science. The primary objective of the programme is to prepare students for successful careers in academia as well as in finance, telecommunications, marketing, medicine and natural sciences.

The graduate will be familiar with mathematical modelling of random events and processes and its applications. He/she will understand the foundations of probability theory, mathematical statistics, random process theory and optimization. His/her general background will have been extended to a deeper knowledge of random process theory and stochastic analysis, modern statistical methods, or advanced optimization and time series analysis. The graduate will understand the substance of the methods, grasp their mutual relationships, and will be able to actively extend them and use them. He/she will know how to apply theoretical knowledge to practical problems in a creative way. The graduate’s ability to think logically, to analyse problems, and to solve non-trivial problems can be put to use in independent and creative jobs in the commercial sector or in academic positions.

Assumed knowledge

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Foundations of probability theory.
- Foundations of mathematical statistics and data analysis.
- Markov chain theory.

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

7.1 Obligatory Courses

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7.2 Elective Courses

Set 1

It is required to earn at least 7 credits from this group.

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Set 2

It is required to earn at least 43 credits from this group. We recommend making a planned choice of subject areas for the final exam and the master’s thesis topic when choosing elective courses.

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Master of Mathematics

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7.3 State Final Exam

Requirements for taking the final exam

- Earning at least 120 credits during the course of the study.
- Completion of all obligatory courses prescribed by the study plan.
- Earning at least 7 credits by completion of elective courses from group I.
- Earning at least 43 credits by completion of elective courses from group II.
- Submission of a completed master’s thesis by the submission deadline.

Oral part of the state final exam

The oral part of the final exam consists of three subject areas. The first subject area is common. The second subject area is selected from three options (2A, 2B, 2C). The third subject area is selected from seven options 3A–3G. One question is asked from the common subject area and one from each selected optional subject area.

Requirements for the oral part of the final exam

Common subject area

1. Foundations of Probability, Statistics and Random Processes

Optional subject area 2: Advanced Models

A choice of one of three options

2A. Econometrics and Optimization Methods

2B. Advanced Statistical Analysis.
   Modern theory of estimation and statistical inference. Regression models for non-normal and correlated data.

2C. Processes in Time and Space.
Optional subject area 3: Special Topics

A choice of one of seven options

3A. Econometric Models
Mathematical economics. Time series with financial applications. Advanced econometrical and statistical models. Multivariate statistical analysis.

3B: Optimization Methods

3C: Spatial Modelling
Spatial modelling and spatial statistics. Foundations of stochastic analysis. Limit theorems in probability theory.

3D: Stochastic Analysis

3E. Statistics in Industry, Trade and Business

3F. Statistics in Natural Sciences

3G. Theoretical Statistics

7.4. Recommended Course of Study

1st year

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
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Optional and Elective Courses 32

2nd year

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Optional and Elective Courses 30
Master of Mathematics

8 Degree Plans - Financial and Insurance Mathematics

Coordinated by: Department of Probability and Mathematical Statistics
Study branch coordinator: doc. RNDr. Jan Hurt, CSc.

This programme provides theoretical and applied education in financial and insurance mathematics. A solid mathematical background provides the foundations for developing disciplines of mathematical modelling in the insurance and banking industry and other financial areas. The graduate will be able to develop financial and insurance products and analyse their profitability and risk.

The graduate will have a deep knowledge of basic mathematical disciplines (mathematical analysis, algebra) and special knowledge in the fields of probability and statistics, stochastic processes, mathematical methods in finance, life and non-life insurance, advanced financial management, risk theory, accounting, and modelling with progressive systems (Mathematica). This knowledge provides tools for effective modelling of financial and insurance products, analysis of their profitability, and risk, and other characteristics important for effective financial management.

Assumed knowledge

It is assumed that an incoming student of this branch has sufficient knowledge of the following topics and fields:

- Foundations of financial mathematics and accounting.
- Foundations of functional programming.

Should an incoming student not meet these entry requirements, the coordinator of the study programme may assign a method of acquiring the necessary knowledge and abilities, which may for example mean taking selected bachelor’s courses, taking a reading course with an instructor, or following tutored independent study.

8.1 Obligatory Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMFM401</td>
<td>Mathematics of Non-Life Insurance 1</td>
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<tr>
<td>NMFM402</td>
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<td>NMFM404</td>
<td>Selected Software Tools for Finance and Insurance</td>
<td>3</td>
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<td>2/0 Ex</td>
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<tr>
<td>NMFM405</td>
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<td>5</td>
<td>2/2 C+Ex</td>
<td>—</td>
</tr>
<tr>
<td>NMFM406</td>
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<td>3</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NMFM408</td>
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<td>3</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMFM409</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NMFM410</td>
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</table>
### Financial and Insurance Mathematics

<table>
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<td>NMFM532</td>
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<td>NMFA14K</td>
<td>Optimisation Theory</td>
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<tr>
<td>NMST531</td>
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<tr>
<td>NMST539</td>
<td>Multivariate Analysis *</td>
<td>5</td>
<td>—</td>
<td>2/2 C+Ex</td>
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</tbody>
</table>

*Courses marked by an asterisk are not offered in English this academic year.

### 8.2 Elective Courses

It is required to earn at least 5 credits from the following elective courses.

<table>
<thead>
<tr>
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<tbody>
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<td>2/0 Ex</td>
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<tr>
<td></td>
<td>Measuring and Management</td>
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<tr>
<td>NMFA15K</td>
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*Courses marked by an asterisk are not offered in English this academic year.

**Recommended Optional Courses**

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<td>Optimisation Theory</td>
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<td>NMST539</td>
<td>Multivariate Analysis *</td>
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<td>2/2 C+Ex</td>
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</table>

**8.3 State Final Exam**

**Requirements for taking the final exam**

- Earning at least 120 credits during the course of the study.
- Completion of all obligatory courses prescribed by the study plan.
- Earning at least 5 credits by completion of elective courses.
- Submission of a completed master’s thesis by the submission deadline.
**Oral part of the state final exam**

The oral part of the final exam consists of three subject areas: “Applied Probability”, “Insurance”, and “Finance and Accounting”. One question is asked from each subject area.

**Requirements for the oral part of the final exam**

1. **Probability and Statistics**


2. **Insurance**


3. **Finance and Accounting**


**8.4 Recommended Course of Study**

**1st year**

<table>
<thead>
<tr>
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<th>Subject</th>
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*Optional and Elective Courses* 7
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*Optional and Elective Courses* 10
Master of Mathematics
Bachelor of Computer Science

1 General Information

Programme coordinator: doc. Petr Kolman, Ph.D.

The study programme Bachelor of Computer Science currently offers the following study branch and its specializations:

Study branch: General Computer Science
Specializations:
- Algorithms and optimization
- Discrete models and structures
- Computational linguistics

The choice of your specialization is up to your decision at the time of enrolling for the final state exam.

2 Degree Plans

The obligatory and elective courses, as specified below, are the same for the three specializations. The specializations differ in one area (question?) of the state final exam and the students are recommended to adjust their choice of elective and optional courses accordingly.

2.1 Obligatory courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
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<th>Summer</th>
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<td>2/2 C+Ex</td>
<td>—</td>
</tr>
<tr>
<td>NDMI002</td>
<td>Discrete Mathematics</td>
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<td>—</td>
<td>2/2 C+Ex</td>
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<tr>
<td>NDMI011</td>
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<td>—</td>
<td>2/2 C+Ex</td>
</tr>
<tr>
<td>NOPT048</td>
<td>Optimization methods</td>
<td>6</td>
<td>—</td>
<td>2/2 C+Ex</td>
</tr>
<tr>
<td>NMAI059</td>
<td>Probability and Statistics</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NAI1101</td>
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<td>6</td>
<td>2/2 C+Ex</td>
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<tr>
<td>NTIN071</td>
<td>Automata and Grammars</td>
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<td>—</td>
<td>2/2 C+Ex</td>
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</table>
Bachelor of Computer Science

<table>
<thead>
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<th>Summer</th>
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<tbody>
<tr>
<td>NPRG030</td>
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<td>Principles of Computers</td>
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<td>3/0 Ex</td>
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<tr>
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* In the course NPRG031 the exam can be taken before obtaining the course credit.

### 2.2 Elective courses

**Set 1**

The student needs to obtain at least 6 credits for courses from this set.

<table>
<thead>
<tr>
<th>Code</th>
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<tbody>
<tr>
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<tr>
<td>NPRG013</td>
<td>Java</td>
<td>6</td>
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<tr>
<td>NPRG035</td>
<td>C# Language and .NET Framework</td>
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**Set 2**

The student needs to obtain at least 34 credits for courses from this set.

<table>
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<tbody>
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<td>3</td>
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<td>NMA1069</td>
<td>Combinatorial and Computational Geometry I</td>
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<td>2/0 Ex</td>
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<tr>
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<td>6</td>
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<tr>
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<td>6</td>
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<td>3</td>
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<td>Programming Methodology and Philosophy of Programming Languages</td>
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** The course can be taken in the summer as well as in the winter semester.

2.3 State Final Exam

The state final exam has three parts in the bachelor programme:

- oral examination in Mathematics
- oral examination in Computer Science
- defense of the bachelor thesis

**Necessary conditions for taking the state final exam**

- obtaining of 180 credits at least
- passing all obligatory courses of a given branch and specialization
- obtaining a given number of credits for the elective courses
- submitting the completed bachelor thesis by the specified deadline.

**Knowledge requirements for the part Mathematics of the State Final Exam**

1. Numbers
   

2. Fundamentals of differential calculus
   
   Real functions of one variable. Continuity, limit of a function (ordinary, infinite). Some specific functions (polynomials, rational functions, trigonometric and inverse trigonometric functions, logarithms and exponential functions). Derivation: the definition, basic rules, theorems about the mean value, higher order derivatives. Applications (examination of properties of functions, Taylor polynomial).

3. Basics of the theory of multivariable functions
   
   Partial derivatives and total differential, theorems about extreme values of multivariable functions, implicit function theorem.

4. Integral
   
   Primitive functions, methods of calculation. Definite (Riemann) integral, applications of the definite integral. Multivariate integrals and Fubini’s theorem.
5. **Metric spaces**
   Definition of a metric space, examples. Continuity, open and closed sets. Compactness.

6. **Elementary algebraic structures**

7. **Vector spaces**
   Basic properties of vector spaces, subspaces, generation, linear dependence and independence. Steinitz (exchange) theorem. Finitely generated vector spaces, basis. Linear mapping.

8. **Scalar product**

9. **Systems of linear equations**

10. **Matrices**

11. **Determinants**

12. **Eigenvalues and eigenvectors**
    Eigenvalues and eigenvectors of linear mapping and square matrix. Calculation, basic properties. Transformation of a matrix to a diagonal form, in the case of different eigenvalues. Jordan normal form of a matrix, in the general case (basic information).

13. **Discrete Mathematics**

14. **Graph Theory**

15. **Probability and Statistics**
    Random events, conditional probability, independence of random events. Random variables, the mean, the distribution of random variables, normal and binomial distribution. Linear combinations of random variables. Point estimates, confidence intervals, hypothesis testing, t-test, chi-square test, linear regression.
16. Logic

17. Algebra
Subgroups, normal subgroups, quotient groups, ideal. Homomorphisms of groups and other structures. Quotient fields.

Knowledge requirements for the part Computer Science of the State Final Exam

1. Automata and languages
Chomsky hierarchy, classes of automata and grammars, determinism and non-determinism. Closure properties of classes of languages.

2. Algorithms and Data Structures

3. Databases

4. Programming languages

5. Computer Architecture and Operating Systems

7. Optimization Methods

8. For specialization Algorithms and optimization
Approximation algorithms for combinatorial problems (satisfiability, independent set, set cover, scheduling). Applications of linear programming in approximation algorithms. The use of probability in the design of algorithms. Voronoi diagrams, ar-
rangements of (complex) hyperplanes, incidence of points and lines, elementary computational geometry algorithms. Error-correcting codes. The probabilistic method - examples of application.

8. For specialization Discrete models and structures


8. For specialization Computational linguistics

Formal languages and automata, basic formalisms for description of a natural language; morphological and syntactic analysis of a natural language; theory of information, language modeling.

2.4 Recommended course of study

The recommended course of study contains all obligatory courses, some elective courses in required extend and some optional courses. The student needs to choose other courses him/herself. The obligatory courses are printed in boldface, the elective courses are printed upright and the optional courses in italics.

First year

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
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<th>Summer</th>
</tr>
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<tbody>
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<td>NMAI054</td>
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<tr>
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<td>—</td>
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<tr>
<td>NSWI120</td>
<td>Principles of Computers</td>
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<tr>
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<td>Introduction to networking</td>
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<td>1/0 Ex</td>
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<tr>
<td>NMAI069</td>
<td>Mathematical skills (^1)</td>
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<td>0/2 C</td>
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<td></td>
<td>Optional courses</td>
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<tr>
<td>NMAI053</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NDMI011</td>
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<tr>
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<tr>
<td>NSWI095</td>
<td>Introduction to UNIX</td>
<td>5</td>
<td>—</td>
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</table>

\(^1\)The course NMAI069 Mathematical skills is highly recommended to students who want to master basic mathematical skills used in mathematical courses. The use of logical thinking is heavily emphasized.

\(*\) In the course NPRG031 the exam can be taken before obtaining the course credit.

Second year

<table>
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<td>Winter</td>
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<td>--------</td>
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<tr>
<td>NMA1052</td>
<td>Propositional and Predicate Logic</td>
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<tr>
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<td>Probability and Statistics</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NMA1054</td>
<td>Mathematical Analysis III</td>
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<td>2/2 C+Ex</td>
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<tr>
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<tr>
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<tr>
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<td>Database Systems</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NPRG0141</td>
<td>Individual Software Project</td>
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**Third year**

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<td>NMA1062</td>
<td>Algebra II</td>
<td>3</td>
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<tr>
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<td>Optional courses</td>
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**Recommended choice of the elective courses for each study plan**

**Algorithms and optimization**

<table>
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<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
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<tbody>
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<td>NDM1012</td>
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<td>6</td>
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<tr>
<td>NDM1082</td>
<td>Introduction to approximation and randomized algorithms</td>
<td>5</td>
<td>2/1 C+Ex</td>
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**Discrete models and structures**

<table>
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<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMA1012</td>
<td>Combinatorics and Graph Theory II</td>
<td>6</td>
<td>2/2 C+Ex</td>
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<tr>
<td>NMA1058</td>
<td>Set Theory</td>
<td>3</td>
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<td>2/0 Ex</td>
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**Mathematical linguistics**

<table>
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<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPF1058</td>
<td>Introduction to General Linguistics</td>
<td>5</td>
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<td>—</td>
</tr>
<tr>
<td>NPF1012</td>
<td>Introduction to Computer Linguistics</td>
<td>3</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
</tbody>
</table>
Master of Computer Science

1 General Information

Programme coordinator: prof. RNDr. Roman Barták, Ph.D.

The study programme Master of Computer Science consists of the following study branches and their specializations:

1 Theoretical Computer Science
   – Algorithms and complexity
   – Nonprocedural programming and artificial intelligence
2 Mathematical Linguistics
3 Discrete Models and Algorithms
   – Discrete mathematics and combinatorial optimization
   – Mathematical structures of computer science
   – Optimization

While your study branch has been specified already in your application, the choice of your specialization (when applicable) is up to your later decision (when enrolling for the state final exam). In this initial part of the present chapter we describe issues that are common for all study branches of the study programme Master of Computer Science.

Assumed knowledge

It is assumed that an incoming student has a sufficient knowledge of mathematics, theoretical computer science and programming. In particular, students are expected to have a good knowledge of mathematics at the level of our bachelor courses NMAI056 Mathematical Analysis III, NMAI059 Probability and Statistics, NMAI062 Algebra I, and NOPT048 Optimization Methods.

Students are also expected to have knowledge equivalent to the courses NDMI002 Discrete Mathematics, NTIN060 Algorithms and Data Structures I, NTIN061 Algorithms and Data Structures II, NTIN071 Automata and Grammars, and NAIL062 Propositional and Predicate Logic. Knowledge from these courses is also expected for the state final exam.

We also expect students to have good knowledge of programming at least at the level of our bachelor courses NPRG030 Programming I, NPRG031 Programming II.

Students missing knowledge in some of the above mentioned areas are suggested to consider taking the relevant bachelor courses in the first year of their Master studies.

Software Project

One of the obligatory courses for students of Mathematical Linguistics is NPRG023 Software Project, a team software project; for students of the other study branches this course is optional. The goal of this subject is to practice team work in large software
Master of Computer Science

projects lasting typically around 9 months. The work on the project is finished by public presentation.

Students can enroll in the courses NPRG023 Software Project and NPRG027 Course Credit for Project anytime, not just in the usual enrollment period of a given academic year. Nevertheless, each student can try to complete these courses at most twice during the studies.

State Final Exam

The state final exam consists of two parts: a defense of the master (diploma) thesis and an oral examination.

Requirements to enroll for the state final exam

- obtaining at least 120 credits,
- passing all obligatory courses of a given branch and specialization,
- obtaining a given number of credits from the elective courses of a given branch and specialization,
- submitting the master thesis by the specified deadline.

Master (diploma) thesis

Students are advised to select the topic of their master (diploma) thesis at the end of the first semester. The departments of the faculty offer many topics for master theses each year and students can also suggest their own topics. Each topic must be approved by the chair of the department responsible for a given study branch and he also approves the advisor for the corresponding student.

After the topic is approved, the student enrolls in the following obligatory courses:

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
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</thead>
<tbody>
<tr>
<td>NSZZ023</td>
<td>Diploma Thesis I</td>
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</tr>
<tr>
<td>NSZZ024</td>
<td>Diploma Thesis II</td>
<td>9</td>
<td>0/6 C</td>
<td>—</td>
</tr>
<tr>
<td>NSZZ025</td>
<td>Diploma Thesis III</td>
<td>15</td>
<td>—</td>
<td>0/10 C</td>
</tr>
</tbody>
</table>

Course credits for these courses are appointed by the thesis advisor on the basis of student’s work on the thesis. We suggest the students to discuss with their advisor the expected amount of work and the milestones for each of these courses. All three courses can be enrolled in both winter and summer semesters.

Oral examination

The oral part of the state final exam has the same structure for all study branches. The student is examined from two or three obligatory areas covering the theoretical foundations of computer science (complexity, computability, and data structures) and from three optional areas specific to a given study branch and selected specialization. For the study branches Theoretical Computer Science and Discrete Models and Algorithms the student will select these three optional examination areas when registering for the final exam. Two of these areas must be from the selected specialization, the remaining area can be selected from other specializations of the study branch. The study branch Mathematical Linguistics has no specializations and the optional part of the oral examination has specific rules (see below).

To simplify the orientation in the courses offered by the faculty, the description of each examination area is accompanied by a list of recommended and suplementary
courses. Note that not all the courses are available in English every year. We recom-
mend students to contact the study branch coordinator for the selected study branch
and discuss individual study plans prior the beginnnings of a semester.

**The obligatory examination areas for the study branches Theoretical
Computer Science and Discrete Models and Algorithms:**

1. **Complexity**
   Hierarchical theorems, constructible functions, relationships among time and space
complexities and among determinism and nondeterminism, Savitch’s theorem, complete
problems for distinct complexity classes (NP, PSPACE, P, P), polynomial time hier-
archy, pseudopolynomial algorithms, strong NP-completeness, complexity class P and
P-completeness, approximation algorithms and schemes, algorithmic paradigms: dy-
namic programming, exhaustive search, greedy algorithms, randomized algorithms.

*Recommended courses:* NTIN062 Complexity I, NTIN063 Complexity II
*Supplementary courses:* NTIN081 Structural Complexity I, NTIN085 Selected Topics
in Computational Complexity I, NTIN017 Parallel Algorithms, NDMI025 Randomized
Algorithms

2. **Computability**
   Algorithmically computable functions, their properties, equivalence of distinct
mathematical definitions, recursive and partial recursive functions, recursive and recur-
sively enumerable sets and their properties, algorithmic undecidable problems (halting
problem), recursion theorem and its applications, Rice theorem, Gödel theorems.

*Recommended courses:* NTIN064 Computability I, NTIN065 Computability II
*Supplementary courses:* NTIN073 Recursion I, NTIN074 Recursion II

3. **Data structures**
   Tree data structures, binary search trees and balanced binary search trees, heaps,
trie, B-trees and their modifications, hashing (collisions), universal hashing, perfect
hashing, sorting in internal and external memory, lower bound on sorting (decision
trees), dynamization of data structures, self-organizing data structures, relaxed search
trees.

*Recommended courses:* NTIN066 Data Structures I, NTIN067 Data Structures II
*Supplementary courses:* NTIN083 Seminar on Data Structures I

**The obligatory examination areas for the study branch Mathematical
Linguistics**

1. **Complexity and computability**
   Methods of algorithm development: divide and conquer, dynamic programming,
greedy algorithms. Amortized complexity, NP-complete problems, Cook-Levin theo-
rem, pseudopolynomial algorithms, strong NP-completeness, complexity class P and
P-completeness, approximation algorithms and schemes, algorithmic paradigms: dy-
namic programming, exhaustive search, greedy algorithms, divide and conquer, algorithmic
computable functions, their properties, equivalence of distinct mathematical definitions, partial recursive functions, recursive and recursively enumerable sets and their properties, algorithmically undecidable problems (halting problem), recursion theorem and its applications, Rice theorem.

**Recommended courses:** NTIN090 Introduction to Complexity and Computability Theory

**Suplementary courses:** see above for the courses for topics 1 and 2 of the study branches I1 and I4.

2. **Data structures**

   Tree data structures, binary search trees and balanced binary search trees, heaps, tries, B-trees and their modifications, hashing (collisions), universal hashing, perfect hashing, sorting in internal and external memory, lower bound on sorting (decision trees), relaxed search trees.

**Recommended courses:** NTIN066 Data Structures I

**Suplementary courses:** NTIN067 Data Structures II, NTIN083 Seminar on Data Structures I

---

**2 Degree Plans - Theoretical Computer Science I1**

**Coordinated by:** Department of Theoretical Computer Science and Mathematical Logic

**Study branch coordinator:** Prof. RNDr. Roman Barták, Ph.D.

2.1 **Obligatory courses**

<table>
<thead>
<tr>
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<th>Subject</th>
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<th>Summer</th>
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<td>2/1 C+Ex</td>
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</tr>
<tr>
<td>NTIN063</td>
<td>Computability I</td>
<td>3</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NTIN066</td>
<td>Data Structures I</td>
<td>3</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NAIL065</td>
<td>Mathematical Structures</td>
<td>6</td>
<td>2/2 C+Ex</td>
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<td>0/4 C</td>
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<td>Diploma Thesis II</td>
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<td>Diploma Thesis III</td>
<td>15</td>
<td>0/10 C</td>
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2.2 **Elective courses**

The student needs to obtain at least 60 credits for the courses from this set.

<table>
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<td>NAIL076</td>
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<td>NAIL069</td>
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<td>Representations of Boolean Functions</td>
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<td>2/0 Ex</td>
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<td>Neural Networks</td>
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</table>
2.3 State Final Exam

a) Specialization **Algorithms and Complexity**

**Examination areas**

1. Recursion and structural complexity
2. Theory of algorithms
3. Concrete algorithms

**Knowledge requirements**

1. *Recursion and structural complexity*

   Arithmetical hierarchy of classes of sets, classes of infinite branches of computable trees, low basis theorem, diagonally non-recursive functions, arithmetical forcing, 1-generic sets, algorithmic randomness, properties of 1-random sets and their degrees probabilistic complexity classes, Shannon theorem, non-uniform complexity classes, polynomial time hierarchy, relations of distinct complexity classes, separation of distinct complexity classes, properties of sparse sets, foundations of cryptography.

   **Recommended courses:** NTIN073 Recursion I, NTIN074 Recursion II, NTIN081 Structural Complexity I, NTIN082 Structural Complexity II

   **Supplementary courses:** NTIN085 Selected Topics in Computational Complexity I, NTIN086 Selected Topics in Computational Complexity II

2. *Theory of algorithms*

   Randomized algorithms: parameters of randomized algorithms, probabilistic complexity classes (BPP, RP, ZPP) and examples of problems from these classes), random binary search trees.


   Deterministic algorithms: measures of complexity (the worst case complexity, expected complexity, amortized complexity), probabilistic distribution of input data, statistical method for estimates of time complexity based on experiments, interpretation of statistical results.

   **Recommended courses:** NTIN063 Complexity II, NTIN017 Parallel Algorithms, NTIN018 Probabilistic Analysis of Algorithms, NTIN081 Structural Complexity I, NMAI060 Probabilistic Methods, NMAI061 Methods of Mathematical Statistics

   **Supplementary courses:** NDMI025 Randomized Algorithms
3. Concrete algorithms

Sorting: Comparison-based sorting algorithms and their complexity (Shellsort, Mergesort, Heapsort, Quicksort), general sorting algorithms (bucketsort, hybridsort), median algorithms, sorting networks, parallel Mergesort, external sorting.

Algebraic algorithms: matrix multiplication algorithms and their applications, fast discrete Fourier transformation, LUP-decomposition, primality testing algorithms.

Graph algorithms: planarity algorithm, algorithms for maximum network flow and their application, algorithms for transitive closure, Euler tour, parallel algorithms for connectedness and bi-connectedness, least cost path algorithms, minimum spanning tree algorithms.

Algorithms for satisfiability.

Recommended courses: NTIN067 Data Structures II, NDMI010 Graph Algorithms, NTIN017 Parallel Algorithms, NAIL021 Boolean Functions and Their Applications, NDMI025 Randomized Algorithms


b) Specialization Non-procedural programming and artificial intelligence

Examination areas

1. Logic and Computational Complexity
2. Artificial Intelligence
3. Nonprocedural Programming
4. Neural Networks
5. Adaptive Agents and Evolutionary Algorithms
6. Robotics

Knowledge requirements

1. Logic and computational complexity


   Measures of computational complexity, complexity classes (P, NP, PSPACE, NPSPACE, LOGSPACE), NP-hard and NP-complete problems. Complexity of algorithms in artificial intelligence, searching, resolution.

Recommended courses: NAIL062 Propositional and Predicate Logic, NTIN062 Com-
2. Artificial Intelligence


Recommended courses: NAIL069 Artificial Intelligence I, NAIL070 Artificial Intelligence II
Supplementary courses: NAIL004 Seminar on Artificial Intelligence I, NAIL052 Seminar on Artificial Intelligence II, NAIL021 Boolean Functions and Their Applications, NAIL031 Representations of Boolean Functions, NAIL029 Machine Learning, NOPT042 Constraint Programming, NAIL071 Planning and Scheduling, NAIL068 Human-like Artificial Agents, NAIL094 Decision Procedures and Verification

3. Nonprocedural programming


Recommended courses: NAIL078 Lambda Calculus and Functional Programming I, NAIL076 Logic Programming I, NOPT042 Constraint Programming

4. Neural networks

Neurophysiological fundamentals: the structure of a neuron, types of synapses, main parts of the brain. Models for supervised learning: perceptron, back-propagation training algorithm, strategies to speed up the training process, internal knowledge representation, generalization, regulation techniques. Associative memories: Hebbian learning, BAM, Hopfield model, energy function and the search for sub-optimal solutions.

Recommended courses: NAIL002 Neural Networks, NAIL013 Applications of Neural Networks Theory
Suplementary courses: NTIN084 Bioinformatics Algorithms, NAIL060 Neural Networks Implementation I, NAIL015 Neural Networks Implementation II, NAIL065 Evolutionary Robotics, NDBI023 Data Mining

5. Adaptive agents and evolutionary algorithms


Recommended courses: NAIL068 Human-like Artificial Agents, NAIL025 Evolutionary Algorithms I, NAIL086 Evolutionary Algorithms II, NAIL087 Computer and Cognitive Sciences I
Suplementary courses: NAIL071 Planning and Scheduling, NAIL054 Adaptive Agents, NAIL082 Seminar on Human-like Artificial Agents, NAIL065 Evolutionary Robotics, NAIL002 Neural Networks, NAIL088 Computer and Cognitive Sciences II, NAIL096 Multi-agent Systems

6. Robotics

Software implementation: system design, modeling, simulation, programming for specific runtime environments.

*Recommended courses:* NAIL028 Introduction to Mobile Robotics, NPGR001 Computer Vision and Robotics, NAIL071 Planning and Scheduling, NSWE001 Embedded and Real Time Systems

*Suplementary courses:* NAIL029 Machine Learning, NAIL065 Evolutionary Robotics, NAIL068 Human-like Artificial Agents, NAIL025 Evolutionary Algorithms I, NAIL101 Probabilistic Robotics, NAIL070 Artificial Intelligence II

### 3 Degree Plans - Mathematical Linguistics I3

*Coordinated by:* Institute of Formal and Applied Linguistics  
*Study branch coordinator:* Doc. RNDr. Markéta Lopatková, Ph.D.

#### 3.1 Obligatory courses

<table>
<thead>
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<th>Subject</th>
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<th>Summer</th>
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<td>NPFL071</td>
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<td>NPFL072</td>
<td>Software Project</td>
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<td>Introduction to Complexity and Computability ¹</td>
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<td>2/1 C+Ex</td>
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<td>NTIN067</td>
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<td>0/10 C</td>
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¹ Instead of the course NTIN090 Introduction to Complexity and Computability Theory students may take the pair of courses NTIN062 Complexity I, NTIN064 Computability I

The courses NPFL067 Statistical Methods in Natural Language Processing I and NPFL092 NLP Technology can be studied already during the bachelor studies.

#### 3.2 Elective courses

The student needs to obtain at least 35 credits for the courses from this set.

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</table>
3.3 State Final Exam

Examination areas

The I3 branch is not divided into specializations. The examination area 1 is obligatory for all students of the branch; the student must select the second and third examination area from the areas 2-5. Upon explicit request approved by the responsible teacher, the student can choose one area from the areas 2-5 and one of the examination areas from the following list (rules of the study program Computer Science, par. B.4.): Artificial Intelligence, Neural Networks, Adaptive agents and evolutionary algorithms (from the branch I1, specialization Non-procedural Programming and Artificial Intelligence), or the area Image Analysis and Processing, Computer Vision and Robotics (branch I2, specialization Computer Graphics).

1. Fundamentals of Natural Language Processing
2. Statistical Methods and Machine Learning in Computational Linguistics
3. Applications in Natural Language Processing
4. Linguistic Theories and Formalisms
5. Speech Analysis and Synthesis, Dialog Systems

Knowledge requirements

1. Fundamentals of Natural Language Processing

Fundamentals of general linguistics (basic linguistic terms and concepts, function and form). System of layers in language description (phonetics, phonology, morphology,
surface/deep syntax, semantics, pragmatics). Dependency syntax, formal definition of dependency trees, their characteristics (dependency relation, coordination, projectivity). Chomsky hierarchy of languages, context free languages, phrase grammars for a natural language. Design and evaluation of linguistic experiments, evaluation metrics (precision, recall, f-measure, statistical significance etc.) Basic stochastic methods (generative, discriminative; source-channel model; HMM). Language modeling, basic methods for training stochastic models (maximal likelihood, EM). Basic algorithms (Trellis, Viterbi, Baum-Welch).

Recommended courses: NPFL067 Statistical Methods in Natural Language Processing I and a selection of one of the courses from NPFL063 Introduction to General Linguistics, NPFL075 Prague Dependency Treebank and NPFL106 General Linguistics

2. Statistical Methods and Machine Learning in Computational Linguistics


Recommended courses: NPFL067 Statistical Methods in Natural Language Processing I, NPFL068 Statistical Methods in Natural Language Processing II, NPFL054 Introduction to Machine Learning, NPFL070 Language Data Resources

3. Applications in Natural Language Processing


Recommended courses: NPFL093 NLP Applications, NPFL094 Morphological and Syntactic Analysis, NPFL087 Statistical Machine Translation, NPFL103 Information Retrieval

4. Linguistic Theories and Formalisms

Functional Generative Description (basic characteristics, system of layers, theory of valency, language meaning). Government and binding (nativism, X-bar, movement, trace, binding). Other basic grammar formalisms (unification-based grammars, feature structures, HPSG, LFG, categorial grammars, TAG). Formal semantics. Prague De-

*Recommended courses:* NPFL106 General Linguistics, NPFL083 Linguistic Theories and Grammar Formalisms, NPFL075 Prague Dependency Treebank, NPFL082 Information Structure of Sentence and Discourse Structure, NPFL006 Introduction to Formal Linguistics

5. *Speech Analysis and Synthesis, Dialog Systems*


*Recommended courses:* NPFL038 Fundamentals of Speech Recognition and Generation, NPFL079 Algorithms in Speech Recognition, NPFL099 Statistical Dialog Systems

4 Degree Plans - Discrete Models and Algorithms I4

**Coordinated by:** Department of Applied Mathematics

**Study branch coordinator:** Doc. RNDr. Martin Klazar, Dr.

4.1 Obligatory courses

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1. The course is compulsory only for the two specializations Discrete Mathematics and Combinatorial Optimization, Mathematical Structures of Computer Science; it is elective for the specialization Optimization.

2. The course is compulsory only for the specialization Optimization; it is elective for the other specializations.
4.2 Elective courses

The student needs to obtain at least 45 credits for the courses from this set.

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### 4.3 State Final Exam

a) Specialization *Discrete Mathematics and Combinatorial Optimization*

#### Examination areas

1. Combinatorics and graph theory
2. Probabilistic methods and randomized algorithms
3. Combinatorial optimization

#### Knowledge requirements

1. *Combinatorics and graph theory*
   
   Coloring of graphs, regular graphs, connectivity of graphs, special properties of oriented graphs, algebraic properties of graphs, matching theory, Ramsey theory, infinite combinatorics, structural properties of set systems.

2. *Probabilistic methods and randomized algorithms*
   
   Combinatorial counting, generating functions, recurrences, basic probability models, linearity of expectation, applications of variance, application in specific examples, asymptotic estimates of functions, random constructions and algorithms.
3. **Combinatorial optimization**

Graph algorithms, algebraic and arithmetic algorithms, theory of polyhedra, problem of the traveling salesman, special matrices, integrality, matchings and flows in networks, matroid theory, ellipsoid method.

### Recommended courses

<table>
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b) Specialization *Mathematical Structures of Computer Science*

### Examination areas

1. Combinatorial and computational geometry
2. Algebraic and topological methods in Computer Science
3. Number theory and category theory in Computer Science

### Knowledge requirements

1. **Combinatorial and computational geometry**

   Geometric problems in spaces with finite dimension, combinatorial properties of geometric configurations, algorithmic applications, design of geometric algorithms, geometric representations of graphs.

2. **Algebraic and topological methods in Computer Science**


3. **Number theory and category theory in Computer Science**

   Categories, functors, transformations, specific examples. Limits and colimits, specific constructions and generation of further constructions. Adjunction, relation to

**Recommended courses**

<table>
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<tr>
<th>Code</th>
<th>Subject</th>
<th>Credits</th>
<th>Winter</th>
<th>Summer</th>
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c) Specialization *Optimisation*

**Examination areas**

1. Nonlinear programming
2. Optimisation processes
3. Parametric, multiobjective and integer programming
4. Non-smooth optimization and stochastic dynamical models

**Knowledge requirements**

1. *Nonlinear programming*


2. *Optimisation processes*

   Continuous: the maximum principle for nonlinear problems of various types. Conditions for optimality in the basic problems of the calculus of variations. Linear problems on the minimization of time.
Discrete: Classification of problems and their relation to the problem of nonlinear programming. Linear and quadratic problems. Fundamentals of the control of Markov systems. Discrete dynamical programming - optimization with respect to the initial state, final state, and both the initial and final state.

3. Parametric, multiobjective and integer programming

Domains of stability of the solution. Domains of solvability. Solvability functions for one-parametric and multiobjective programming. Various approaches for solving problems with several criteria.


4. Non-smooth optimization and stochastic dynamical models


**Recommended courses**

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