**GENERAL SYLLABUS FOR DOCTORAL STUDIES IN COMPUTATIONAL MATHEMATICS**
incl. general syllabus for programmes leading to a licentiate degree

Admissions to doctoral studies at Stockholm University should be mainly to programmes leading to a doctoral degree.

National regulations concerning doctoral studies can be found in the *Higher Education Ordinance*, Chapters 5-7, 10, 12 and Appendix 2. In addition, the following rules and regulations are in effect at Stockholm University: *Admission Regulations for Doctoral Studies at Stockholm University, Regulations for Third-Cycle Education and Examinations at Stockholm University*, and *Local System of Qualifications for Stockholm University.*

The general syllabus was approved by the board of Faculty of Sciences on 2018-10-17.

# 1   Subject Description

The subjects of Computational Mathematics include studies of computations and development of computational methods in scientific fields where algorithms, inference methods, numerical methods and symbolic computations play central roles. More specifically, these include: *numerical analysis, symbolic computations, computer science, and computational statistics*.

*Numerical analysis*: algorithms in, e.g., numerical linear algebra and/or numerical solutions of partial differential equations.

*Symbolic computations*: development of algorithms and software for manipulating mathematical expressions and other mathematical objects.

*Computer science*: computational computer science in two sub-areas: (i) advanced data processing by development of models, algorithms, and simulations to understand natural systems and solve complex problems, (ii) program logic, including program verification, proof assistants and applications of proof theory in programming, functional programming, and semantics of programming languages.

*Computational statistics*: design of algorithms for computationally intensive statistical methods, such as bootstrap, jackknife, Markov Chain Monte Carlo (MCMC), which are unfeasible to perform without computers. It also includes statistical machine learning, which is a combination of statistical techniques and machine learning forming a central part of the field of artificial intelligence.

# 2   Programme Objectives

In addition to the provisions for first- and second-cycle studies, third-cycle (doctoral) studies should provide the knowledge and skills required to be able to conduct independent research.

The programme leads to a licentiate or doctoral degree. The objectives defined for these degrees in the *Higher Education Ordinance* are presented in sections 5 and 6 below.

## 3 Prerequisites and Entry Requirements

Admission to doctoral studies requires that the applicant meets the general and specific entry requirements, in addition to being otherwise capable of completing the training.

### 3.1 General entry requirements

In order to meet the general eligibility requirements, the applicant must have completed courses equivalent to at least 240 higher education credits (4 years full time study), of which 60 credits must be in the second cycle, or have otherwise acquired equivalent knowledge in Sweden or elsewhere.

The academic area board may permit an exemption from the general entry requirements for an individual applicant under special circumstances.

### 3.2 Special entry requirements

In order to meet the special eligibility requirements, the applicant must have completed courses equivalent to at least 60 credits in mathematical subjects of which at least 30 credits are in either numerical analysis or computer science, and at least 15 credits are from independent thesis study in mathematically related subjects.

The scientific literature in the area is to a large extent written in English. Good knowledge in English is hence a prerequisite for pursuing a doctoral degree in computational mathematics.

## 4 Selection and Admission

The selection between candidates who meet the entry requirements will be made according to their ability to benefit from the training. The fact that an applicant is deemed able to transfer credits from previous training or professional experience may not alone give the applicant priority over other applicants in the selection process. Admission decisions are made in according to the current delegation policies.

Criteria that are used to judge the ability to benefit from the training are: the applicant's documented knowledge with relevance to the research area, written and oral communication skills, ability of analytical thinking, creativity, sense of initiative, independence and collaborative skills. The judgement is based on previous studies and grades, quality of the thesis, references, relevant experience, the written application and interviews.

## 5 Programmes Leading to a Doctoral Degree

### 5.1 General provisions

Programmes leading to a doctoral degree require four years of full-time study (240 higher education credits). The programme consists of a course component, which comprises at least 60 credits, and a thesis component, which comprises at least 150 credits.

Although the course component precedes the thesis component, the student is encouraged to discuss the topic of the thesis at an early stage.

**Objectives for doctoral degrees according to the Higher Education Ordinance**

**Knowledge and understanding**
For the doctoral degree, the student must:

- demonstrate broad knowledge in, and a systematic understanding of, the field of research, together with deep and current specialist knowledge in a defined part of this field;
- demonstrate familiarity with research methodology in general and the methods of the specific field of research in particular.

**Skills and Abilities**
For the doctoral degree, the student must:

- demonstrate an ability to engage in scholarly analysis and synthesis, as well as in independent, critical review and assessment of new and complex phenomena, issues, and situations;
- demonstrate an ability to identify and formulate issues critically, independently, creatively, and with scholarly precision; to plan and conduct research and other advanced tasks using appropriate methods within specified time limits; and to review and evaluate such work;
- demonstrate an ability to make a substantial contribution to the development of knowledge through their own research in a thesis;
- demonstrate an ability, in both national and international contexts, orally and in writing, to present and discuss research and research findings authoritatively in dialogue with the scholarly community and society in general;
- demonstrate an ability to identify areas where further knowledge is required;
- demonstrate the potential to contribute to social development and support the learning of others, both in the fields of research and education and in other qualified professional contexts.

**Judgement and approach**
For the doctoral degree, the student must:

- demonstrate intellectual independence and scholarly integrity, as well as an ability to make ethical assessments relating to research;
- demonstrate specialized insight into the potential and limitations of research, its role in society, and the responsibility of the individual for how it is used.

**5.2  Individual study plan**

An individual study plan must be drawn up for each doctoral student. The individual study plan should include:

- a research plan, including a timetable;
- information relating to how the supervision is organized;
- a plan of which courses/what type of courses the doctoral student is going to take;
- a description of other academic activities, such as participation in seminars and reading courses;
- a description of other obligations the student and the department may have during the training period;
- a financial plan covering the entire period of study;
- if the training is not funded by means of employment, the financial plan should specify what social benefits apply to the type of funding in question, for example in the event of illness or parental leave.

The individual study plan should be drawn up in consultation with the doctoral student and his/her supervisor, and be reviewed at least once a year. The individual study plan should be adopted and reviewed in accordance with the current delegation policies. When the individual study plan is reviewed, it should be specified how the doctoral studies relate to the qualitative targets outlined in the *Higher Education Ordinance*.

## 5.3  Course and instruction

The course component comprises at least 60 credits, of which at least 45 credits should be at the doctoral level. To ensure a wide knowledge in the subject, the student must complete a program-defining block of four compulsory doctoral courses each of 7.5 credits: *Numerical Analysis, Symbolic Computation, Computer Science, and Computational Statistics*. In addition, the student must complete the course 'Ethics in research and proper scientific conduct' which aims at ensuring the requirements of good knowledge in ethics and scientific conduct in the higher education ordinance. The student must also complete at least one pedagogical course.

The remaining courses are chosen in consultation with the supervisor.

Doctoral students are expected to participate actively in seminars discussing current research findings. Courses or instruction may be provided in collaboration with other departments. Doctoral students are expected to make use of the provided opportunities to attend guest lectures, both in their own and related subject areas.

## 5.4  Thesis

As part of the training, the student will write an academic thesis. The thesis should reflect the doctoral student's ability to complete the selected research task in a scholarly and independent manner, with or without collaboration. The thesis should be of such quality that it could be considered to meet reasonable requirements for publication in an academic journal of good quality. The doctoral thesis should be written either as a unified, coherent academic work

(monograph) or as a compilation of academic papers with a summary. The papers may be co-authored with other people, but the doctoral student's contributions must be clearly distinguishable.

The thesis should be written in English. The department is responsible for the English summary of the thesis being translated into Swedish.

### 5.5 Supervision

Each doctoral student should be assigned a principal supervisor and at least one assistant supervisor. At least one of the supervisors should have a docentship and at least one should have received training in supervision or be considered to have corresponding qualifications. Decisions regarding supervisors are made in accordance with the current delegation policies.

A doctoral student is entitled to change supervisors upon request to the departmental board, in which case the individual study plan should be revised.

### 5.6 Examination and public defense

In order to receive a degree, the student must have received a passing grade on the thesis and the examinations included in the programme. Each course is usually concluded with a written or oral examination. In some cases, continuous examination may take place during teaching sessions or laboratory work. Examinations are assessed using the grades Pass or Fail.

The thesis should be defended orally at a public defense seminar. The defense seminar should follow the regulations of the Academic Area of Science at Stockholm University.

### 5.7 Credit transfer

Provisions concerning credit transfer can be found in the *Higher Education Ordinance,* Chapter 6, sections 6-8.

Courses that were part of the specific entry requirements cannot be given credit for as part of the doctoral degree.

Decisions regarding credit transfer are made in accordance with current delegation policies.

## 6 Programmes Leading to a Licentiate Degree

Under special circumstances, the academic area board may decide to allow admissions to programmes that lead to a licentiate degree worth at least 120 higher education credits. An assessment that funding can be secured for the time required to complete a licentiate degree, but not a doctoral degree, does not alone constitute such a special circumstance.

Decisions to admit students to programmes that lead to a licentiate degree are made in accordance with current delegation policies.

In cases where a student who has been admitted to a programme leading to a licentiate degree student wishes to pursue a doctoral degree, a new academic review and an analysis of the financial plan will be carried out before a decision to admit the student to a programme leading to a doctoral degree can be made in accordance with current delegation policies.

## 6.1 General provisions

A third-cycle programme comprising at least 120 credits, or a part comprising at least 120 credits of a third-cycle programme leading to a doctoral degree, may be completed with a licentiate degree. The program consists of a thesis component comprising at least 75 credits, and a course component consisting of at least 30 credits.

Although the course component precedes the thesis component, the student is encouraged to discuss the topic of the thesis at an early stage.

**Objectives for licentiate degrees according to the Higher Education Ordinance**

**Knowledge and understanding**
For the licentiate degree, the student must:

- demonstrate knowledge and understanding in the field of research, including current specialist knowledge in a limited area of this field, as well as specialized knowledge of research methodology in general and the methods of the specific field of research in particular.

**Skills and abilities**
For the licentiate degree, the student must:

- demonstrate an ability to critically, independently, creatively, and with scholarly precision identify and formulate issues, and to plan and, using appropriate methods, complete a limited research project and other qualified tasks within specified time limits, so as to contribute to the development of knowledge and to evaluate this work;
- demonstrate an ability to present and discuss research and research findings clearly, in dialogue with the scholarly community and society in general, orally and in writing, in both national and international contexts;
- demonstrate the skills required to participate independently in research and development and to work independently in other advanced contexts.

**Judgement and approach**
For the licentiate degree, the student must:

- demonstrate an ability to make assessments of ethical aspects of their own research;
- demonstrate insight into the possibilities and limitations of research, its role in society, and our responsibility for how it is used;

- demonstrate an ability to identify their need of further knowledge and to take responsibility for developing their knowledge.

## 6.2 Individual study plan

The individual study plan should be written in the same way as for a doctoral degree, see section 5.2.

## 6.3 Courses and instruction

A program-defining block of four courses is compulsory, each with 7.5 credits: *Numerical Analysis, Symbolic Computation, Computer Science and Computational Statistics.*

The remaining courses are chosen in consultation with the supervisor.

Doctoral students are expected to participate actively in seminars discussing current research findings. Courses or instruction may be provided in collaboration with other departments. Doctoral students are expected to make use of the provided opportunities to attend guest lectures, both in their own and adjacent subject areas.

## 6.4 Thesis

As part of the training, the student will write a licentiate thesis. The thesis should be of such quality that it could be considered to meet reasonable requirements for publication in an academic journal of good quality.

## 6.5 Supervision

See section 5.5.

## 6.6 Examination

The first paragraph of section 5.6 also applies to licentiate degrees. The examination of a licentiate thesis takes place in connection with a publicly advertised licentiate seminar and should follow the regulations of the Academic Area of Science at Stockholm University.

## 6.7 Credit transfer

Provisions concerning credit transfer can be found in the *Higher Education Ordinance,* Chapter 6, sections 6-8.
Courses that were part of the specific entry requirements cannot be given credit for as part of the licentiate degree.

Decisions regarding credit transfer are made in accordance with current delegation policies.