LUND UNIVERSITY

Faculty of Science

NUMN33, Numerical Analysis: Numerical Methods for Partial Differential Equations, 7.5 credits

Numerisk analys: Numeriska metoder för partiella differentialekvationer, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2024-04-16. The syllabus comes into effect 2024-04-16 and is valid from the spring semester 2025.

General information

This is an elective course for second-cycle studies for a degree of Master of Science in Mathematics with specialisation in Numerical Analysis, and an elective course for second-cycle studies for a degree of Master of Science in Computational Science.

Language of instruction: English

Main field of study	*Specialisation*
Computational Science	A1F, Second cycle, has second-cycle course/s as entry requirements
Mathematics with specialization in Numerical Analysis	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The purpose of the course is to deepen the student's knowledge of partial differential equations and also provide the opportunity to work with relevant simulation problems and software in connection with partial differential equations. The course is a continuation of NUMN32, Numerical methods for differential equations, 7.5 credits.

Knowledge and understanding

On completion of the course, students shall be able to:

- understand how concepts from functional analysis are used to develop and analyse numerical algorithms for elliptic partial differential equations,
- discretize partial differential equations using the Finite Element Method,
- independently implement problems and apply suitable solution strategies using DUNE-FEM,
- independently identify an appropriate numerical method and select suitable parameters with regard to accuracy and efficiency requirements,
- independently proceed from observation and interpretation of results to conclusion, and present the conclusions on a scientific basis in a free report format

Competence and skills

On completion of the course, students shall be able to:

- derive simple error estimates for elliptic problems,
- give examples of important fields of applications in which the algorithms occurring in the course are important,
- independently apply and critically evaluate numerical methods found in the DUNE-FEM software packages,
- present in writing and orally, with adequate terminology, an account of concepts presented in the course,
- independently implement problems and apply suitable solution strategies based on DUNE-FEM,
- present solutions of problems and numerical results in written and oral form

Judgement and approach

On completion of the course, students shall be able to:

- independently evaluate obtained numerical results with DUNE-FEM in relation to the available theory,
- independently present results and conclusions of numerical experiments performed with DUNE-FEM, in written and oral form, with references and other documentation of work carried out in support of their conclusions.

Course content

The course gives an introduction to error estimates, convergence and stability, as well as existence and regularity of solutions to elliptic differential equations (PDEs). This is followed by an introduction to DUNE-FEM which discusses how elliptic PDEs can be discretized using the Finite Element Method (FEM). In particular it considers:

- Weak theory for elliptic PDEs: existence and error estimates,
- Construction of Finite Elements, e.g. discretization grids, reference elements, degree-of-freedom (DOF) mappings,
- Unified Form Language (UFL) for description of weak forms of partial differential equations,

- Parallelization of Finite Element methods using domain decomposition, and
- Adaptive Finite Elements.

Course design

The teaching consists of lectures. A number of compulsory projects carried out in small groups are included in the course. Attendance at all oral group presentations of the project results is mandatory.

Assessment

The examination consists of a written final report and an appurtenant oral presentation of the projects at the end of the course.

Students who did not pass an assessment in the regular session will be offered another opportunity for assessment during the scheduled period for re-exam.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Grades

Grading scale includes the grades: Fail, Pass, Pass with distinction
To pass the entire course, the student is required to pass the written report and the oral presentation of the projects.

The grade **Pass with distinction** on the whole course is decided by the grade on the project reports in conjunction with the performance at the oral presentation.

Entry requirements

Admission to the course requires English 6/b and at least 90 credits in natural sciences or engineering, of which at least 45 credits should be in mathematics and/or numerical analysis, including knowledge corresponding to the courses NUMA01 Computational Programming with Python, 7.5 credits, and NUMN32 Numerical Methods for Differential Equations, 7.5 credits.

Further information

The course cannot be included in a degree together with the course NUMN18, Numerical analysis for elliptic and parabolic differential equations, 7.5 credits.

The course is offered by the Centre for Mathematical Sciences, Lund University.