LUND UNIVERSITY

Faculty of Science

NUMN28, Numerical Analysis: Numerical Simulations of Flow Problems, 7.5 credits

Numerisk analys: Numeriska simuleringar av flödesproblem, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2021-05-28 and was last revised on 2023-03-28. The revised syllabus applies from 2023-03-28, spring semester 2024.

General Information

The course is an elective course for second-cycle studies for a Degree of Master of Science in mathematics with specialization in Numerical Analysis, and an alternative-compulsory course for a degree of Master of Science in Computational Science with specialisation in Geoscience, Scientific Computing and Physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Mathematics	A1F, Second cycle, has second-cycle course/s as entry requirements
Computational Science	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The overall goal of the course is that the students after completing the course should have acquired basic knowledge in modern numerical methods for non-linear conservation laws, with focus on fluid mechanics.Thereby, students should have acquired knowledge of how numerical simulations are applied and what difficulties may arise in the design of aircraft and wind turbines as well as in climate system research.

Knowledge and understanding

After completing the course the student should be able to:

- give an account of mathematical and numerical difficulties arising with nonlinear conservation laws and shock solutions,
- explain stability and convergence of discontinuous Galerkin methods,
- describe the structure of Jacobian-free Newton-Krylov methods,
- describe multi-grid methods and their use for flow problems.

Competence and skills

After completing the course the student should be able to:

- derive a discontinuous Galerkin method for a general conservation law,
- implement a discontinuous Galerkin method for a one dimensional nonlinear conservation law,
- interpret numerical stability and accuracy problems arising in simulations,
- implement a Jacobian-free Newton-Krylov method with preconditioner,
- implement a multigrid method and apply it to flow problems,
- integrate knowledge from the various parts of the course to address problems within the framework of the course,
- plan and execute qualified tasks within the framework of the course, with appropriate methods within given time-frames.

Judgement and approach

After completing the course, the student should be able:

- to critically evaluate and independently apply methods from the course within a project work,
- evaluate their own responsibility for how the subject is used and discuss the subject's possibilities to contribute to a sustainable social development.

Course content

The course covers:

- Models of computational fluid dynamics
- Hyperbolic conservation laws and their basic properties (weak solutions, weak entropy solutions, shocks)
- Discontinuous Galerkin discretizations
- Simulations of gas dynamics
- Krylov subspace methods with preconditioning
- Jacobian-free Newton-Krylov methods
- Multigrid methods for flow problems

Course design

The teaching consists of lectures. Assignments and a compulsory final project are included in the course. The assignments are not compulsory, but they are preparatory for the compulsory final project.

Assessment

The examination consists of a written report of the final project and an appurtenant oral examination based on the report. The oral examination is only given to those students who have passed the written report.

Students who fail the regular examination are offered a re-examination shortly thereafter.

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.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
The grading scale of the project report is Fail, Pass, and the grading scale for the oral examination of the final project is Fail, Pass, Pass with distinction.

To obtain the grade Pass on the whole course, the student is required to pass the project report and the oral examination.

To obtain the grade Pass with distinction on the oral examination it is required in addition that the student demonstrates a good ability to critically and systematically integrate knowledge from the various parts of the course and handle, analyse and assess various questions posed in the project and at the oral examination. The final grade is determined by the grade for the oral examination.

Entry requirements

For admission to the course English 6/B and at least 30 credits mathematics and additional 60 credits in mathematics and/or physics are required, including knowledge corresponding to the courses NUMN32 Numerical Methods for Differential Equations, 7.5 credits.

Further information

The course may not be included in a higher education qualification together with NUMN14 Finite Volume Methods, 7.5 credits, NUMN23 Iterative Solution of Large Scale Systems in Scientific Computing, 7.5 credits and NUMN24 Finite Volume Methods, 7.5 credits.

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

Subcourses in NUMN28, Numerical Analysis: Numerical Simulations of Flow Problems

Applies from V22

2201 Written Project Report, 3,5 hp
Grading scale: Fail, Pass

2202 Oral Examination, 4,0 hp
Grading scale: Fail, Pass, Pass with distinction