Master in Advanced Mathematics and Mathematical Engineering
**Sumari:**

General information MAMME

- Introduction
- Admission
- Curriculum
- Competencies
- Professional opportunities

Program

- Study program
- MAMME courses
- Master thesis

Subjects MAMME
General information MAMME

Introduction

Admission

Curriculum

Competencies

Professional opportunities
The master’s degree in Advanced Mathematics and Mathematical Engineering (MAMME) is a master program in mathematics offered at School of Mathematics and Statistics (FME).

The courses offered in MAMME allow our students to design their curriculum, with two different orientations: a pure mathematics curriculum (oriented to research in fundamental mathematics) or an applied mathematics curriculum (preparing them for applied mathematics research and for interdisciplinary team working, in collaboration with engineers, physicists, biologists, economists, etc.).

The curriculum comprises a total of 60 ECTS, divided in 45 ECTS for courses and 15 ECTS for the master’s thesis. It is intended to be completed in one academic year. In addition, MAMME offers the possibility of registering up to 22.5 ECTS in other masters in mathematics or statistics, or in other UPC master programs, opening the path for an interdisciplinary curriculum based on selected courses in masters in engineering and applied sciences. See the MAMME focus proposals at http://mamme.masters.upc.edu/en.

The Catalan Agency for the Management of University and Research Grants (AGAUR) has distinguished MAMME with the International Master’s Programme (IMP) mention in the 2013 call.

Consult the list of candidates admitted.

<table>
<thead>
<tr>
<th>Pre-enrolment</th>
<th>Pre-enrolment period open.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting</td>
<td>September and February</td>
</tr>
<tr>
<td>Duration</td>
<td>One academic year</td>
</tr>
<tr>
<td>ECTS credits</td>
<td>60</td>
</tr>
<tr>
<td>Delivery</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>Language of instruction</td>
<td>English</td>
</tr>
<tr>
<td>Organised by</td>
<td>School of Mathematics and Statistics (FME)</td>
</tr>
<tr>
<td>International double-degree agreement</td>
<td>Illinois Institute of Technology (United States)</td>
</tr>
<tr>
<td>Academic coordinator</td>
<td>Sonia Fernández Méndez</td>
</tr>
<tr>
<td>Prospective students</td>
<td>MAMME is mainly oriented to graduates in mathematics willing to improve and amplify their skills in mathematics or its applications. Other graduates in engineering or applied sciences, with a solid background in mathematics, are also invited to apply. A minimum of 60 ECTS in mathematics courses is recommended. Candidates whose mathematical background is insufficient can be accepted provided they take additional courses, up to 30 ECTS, to reach the required level.</td>
</tr>
<tr>
<td>Location</td>
<td>School of Mathematics and Statistics (FME)</td>
</tr>
<tr>
<td></td>
<td>Campus Diagonal Sud. Building U. C. Pau Gargallo, 5</td>
</tr>
<tr>
<td></td>
<td>08028 Barcelona</td>
</tr>
<tr>
<td>Fees</td>
<td>€51.46 per ECTS credit. For non-residents who are not EU nationals, the cost is 1.5 times the ordinary cost of one credit. More information about fees, grants and loans and payment options.</td>
</tr>
<tr>
<td>Website</td>
<td><a href="http://mamme.masters.upc.edu">http://mamme.masters.upc.edu</a></td>
</tr>
<tr>
<td>E-mail</td>
<td><a href="mailto:mamme.fme@upc.edu">mamme.fme@upc.edu</a></td>
</tr>
</tbody>
</table>
# General information

<table>
<thead>
<tr>
<th>General requirements</th>
<th><a href="#">Academic requirements for admission to master's degrees</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific requirements</td>
<td>This master is addressed to students with good abstract reasoning, interest in problem solving, strong work habits and a liking for mathematics. A scientific background is required, with basic mathematical foundations. For this reason, a bachelor in mathematics, statistics, physics, engineering, economics or science is recommended. This list is non-exclusive, and all applications will be reviewed on an individual basis.</td>
</tr>
<tr>
<td>Admission criteria</td>
<td>The following elements will be taken into consideration during the evaluation process: academic record, CV, statement of purpose and, if deemed necessary, personal interview and recommendation letters.</td>
</tr>
<tr>
<td>Places</td>
<td>30</td>
</tr>
<tr>
<td>Pre-enrolment</td>
<td>Pre-enrolment period open. How to pre-enrol <a href="#">here</a></td>
</tr>
<tr>
<td>Candidates admitted</td>
<td>Consult the list of candidates admitted <a href="#">here</a></td>
</tr>
</tbody>
</table>
# Master's degree in Advanced Mathematics and Mathematical Engineering

## General information

<table>
<thead>
<tr>
<th>Subjects</th>
<th>ECTS credits</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First semester</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Codes and Cryptography</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Differentiable Manifolds</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Graph Theory</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Mathematical Modelling with Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Non-Commutative Algebra</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Number Theory</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Numerical Methods for Dynamical Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Numerical Methods for Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Quantitative and Qualitative Methods in Dynamical Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td><strong>Second semester</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Course in Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Algebraic Geometry</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Combinatorics</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Commutative Algebra</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Hamiltonian Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Mathematical Models in Biology</td>
<td>7.5</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Master's degree in Advanced Mathematics and Mathematical Engineering

Generic competencies

Generic competencies are the skills that graduates acquire regardless of the specific course or field of study. The generic competencies established by the UFC are capacity for innovation and entrepreneurship, sustainability and social commitment, knowledge of a foreign language (preferably English), teamwork and proper use of information resources.

Specific skills

1. (Research). Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. (Modelling). Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. (Calculus). Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. (Critical assessment). Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
5. (Teaching). Teach mathematics at university level.
Some of the career prospects of master graduates are academic research (by pursuing a PhD in mathematics, science or engineering, for instance), mathematical modeling in industry, finance, statistics, applied research (biomedical research centers, computer vision, etc.)
Program

Study program

MAMME courses

Master thesis
Master’s degree in Advanced Mathematics and Mathematical Engineering

Study program

The master in Advanced Mathematics and Mathematical Engineering (MAMME) is a 60 ECTS (European Credit transfer System) official master program. It is intended to be completed in one academic year, with 45 ECTS in courses and a master thesis (15 ECTS).

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Spring semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 ECTS in COURSES</td>
<td>15 ECTS master THESIS</td>
</tr>
<tr>
<td>≥ 22.5 ECTS in MAMME</td>
<td>≤ 22.5 ECTS in MAMME or other master programs</td>
</tr>
</tbody>
</table>

The courses offered in MAMME allow our students to design their curriculum, with two different orientations:

- a pure mathematics curriculum, oriented to research in fundamental mathematics, or
- an applied mathematics curriculum, preparing them for applied mathematics research and for interdisciplinary team working, in collaboration with engineers, physicists, biologists, economists, etc.

In addition, MAMME offers the possibility of registering up to 22.5 ECTS in other master programs, such as the master in Statistics and Operations Research (MESIO UPC-UB), or the master in Advanced Mathematics offered by Universitat de Barcelona (UB), or other UPC master programs, opening the path for an interdisciplinary curriculum based on selected courses in masters in engineering and applied sciences. See the MAMME focus proposals.

A minimum of 22.5 ECTS in MAMME courses (3 courses) is mandatory. Registration to non-MAMME courses requires the approval of the director of MAMME.

A tutor is assigned to each student, to provide academic guidance for the selection of courses (according to the student background and interests) and for the proposal of the master thesis topic.
Master's degree in Advanced Mathematics and Mathematical Engineering

**MAMME courses**

MAMME courses are offered in five broad fields: Algebra and Geometry, Discrete Mathematics and Algorithmics, Modelling in Engineering and Biomedical Sciences, Differential Equations, and Scientific Computing. The following courses (7.5 ECTS each) are offered:

<table>
<thead>
<tr>
<th>Field</th>
<th>Course</th>
<th>Term</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field: Algebra and Geometry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commutative Algebra</td>
<td></td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>Algebraic Geometry</td>
<td></td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>Differentiable Manifolds</td>
<td></td>
<td>Spring</td>
<td>[not for academic year 2015-2016]</td>
</tr>
<tr>
<td>Number Theory</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Non-Commutative Algebra</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td><strong>Field: Discrete Mathematics and Algorithmics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Codes and Cryptography</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Combinatorics</td>
<td></td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Graph Theory</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td><strong>Field: Modelling in Engineering and Biomedical Sciences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematical Modelling with Partial Differential Equations</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Mathematical Models in Biology</td>
<td></td>
<td>Spring</td>
<td>[modified in 2015-2016]</td>
</tr>
<tr>
<td><strong>Field: Differential Equations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitative and Qualitative Methods in Dynamical Systems</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
<tr>
<td>Hamiltonian Systems</td>
<td></td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>Advanced course in Partial Differential Equations</td>
<td></td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td><strong>Field: Scientific Computing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerical Methods for Dynamical Systems</td>
<td></td>
<td>Autumn</td>
<td>[modified in 2015-2016]</td>
</tr>
<tr>
<td>Numerical Methods for Partial Differential Equations</td>
<td></td>
<td>Autumn</td>
<td></td>
</tr>
</tbody>
</table>
Master’s degree in **Advanced Mathematics** and **Mathematical Engineering**

**Master thesis**

All students are required to write and defend a master thesis during the second term of the academic year. It may be carried out at a [UPC department](#), at a department from another university, at a research centre or at a company.

The timetable and additional information regarding the master thesis can be found at the [FME web page](#).
Subjects MAMME
34950 - CALG - Commutative Algebra

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 725 - MA I - Department of Applied Mathematics I  
**Academic year:** 2015  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** JOSEP ALVAREZ MONTANER  
**Others:** JOSEP ALVAREZ MONTANER - A

### Prior skills

Linear algebra, calculus, topology, analysis.

### Requirements

The two first years of a degree in mathematics.

### Degree competences to which the subject contributes

**Specific:**
1. **RESEARCH.** Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.  
2. **CALCULUS.** Obtain (exact or approximate) solutions for these models with the available resources, including computational means.  
3. **CRITICAL ASSESSMENT.** Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

**Transversal:**
4. **SELF-DIRECTED LEARNING.** Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.  
5. **EFFICIENT ORAL AND WRITTEN COMMUNICATION.** Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.  
6. **THIRD LANGUAGE.** Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.  
7. **TEAMWORK.** Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.  
8. **EFFECTIVE USE OF INFORMATION RESOURCES.** Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

### Teaching methodology

Teaching Classes, resolution of problems

### Learning objectives of the subject
Basic course in Commutative Algebra. An introduction to rings, ideal, primary decomposition, noetherian rings, integral extensions, completions and dimension theory.

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours large group:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time:</strong> 187h 30m</td>
<td>60h</td>
<td>127h 30m</td>
</tr>
<tr>
<td></td>
<td>32.00%</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
# 34950 - CALG - Commutative Algebra

## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rings and ideals</strong></td>
<td></td>
<td>It covers rings, ideals, radicals, extensions, and contractions.</td>
</tr>
<tr>
<td><strong>Modules</strong></td>
<td></td>
<td>General properties of modules. Tensor product.</td>
</tr>
<tr>
<td><strong>Rings and modules of fractions</strong></td>
<td>18h</td>
<td>Introduction to rings and modules of fractions</td>
</tr>
<tr>
<td><strong>Primary decomposition</strong></td>
<td>18h</td>
<td>Classical primary theory. First theorems.</td>
</tr>
<tr>
<td><strong>Integral dependence</strong></td>
<td>18h</td>
<td>Definition of integral dependence. Theorems of going-up and going-down.</td>
</tr>
<tr>
<td><strong>Chain conditions</strong></td>
<td><strong>Learning time:</strong> 18h</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Theory classes: 6h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
<td></td>
</tr>
</tbody>
</table>

**Description:**
Chain conditions on sets, modules, rings.

<table>
<thead>
<tr>
<th><strong>Noetherian rings</strong></th>
<th><strong>Learning time:</strong> 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
</tbody>
</table>

**Description:**
They play a central role in Commutative Algebra and Algebraic Geometry.

<table>
<thead>
<tr>
<th><strong>Artin rings</strong></th>
<th><strong>Learning time:</strong> 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
</tbody>
</table>

**Description:**
A good examples of noetherian rings. In some sense the simpliest.

<table>
<thead>
<tr>
<th><strong>Discrete valuation rings</strong></th>
<th><strong>Learning time:</strong> 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
</tbody>
</table>

**Description:**
The next case. Noetherian rings of dimension one.

<table>
<thead>
<tr>
<th><strong>Completions</strong></th>
<th><strong>Learning time:</strong> 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
</tbody>
</table>

**Description:**
To deal with topologies, completions, filtrations and graded rings.
34950 - CALG - Commutative Algebra

**Dimension theory**

<table>
<thead>
<tr>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Self study: 12h</td>
</tr>
</tbody>
</table>

**Description:**
A brief introduction to Hilbert functions and dimension theory.

**Qualification system**
Continuous assessment, a final exam (if necessary)

**Bibliography**

**Basic:**
34951 - NCA - Non-Commutative Algebra

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
727 - MA III - Department of Applied Mathematics III
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: ENRIC VENTURA CAPELL
Others: ENRIC VENTURA CAPELL - A

Prior skills
The concept of group and subgroup, and the concept of homomorphism. Basic algebraic properties, binary operations, their properties. Equivalence relations and related set-theoretic properties.

Requirements
The basic algebra courses from the degree in mathematics.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34951 - NCA - Non-Commutative Algebra

Teaching methodology

Classes follow the traditional structure of lecture by the professor, together with the assignment of problems and exercises for the students to solve and present, either in written or in oral form.

Learning objectives of the subject

The main goal is to introduce the student into the basic ideas and techniques of non-commutative algebra, to the extent of being able to enroll into some initial research project in the area, if there is interest to do so.

Non-commutative algebra plays a significant role in the research panorama in mathematics today, but is underrepresented along the curriculum at the FME degree in mathematics. The main goal of the present topic is to fill this gap offering to the student a general but consistent introduction into the topic.

We'll center our attention towards the so-called "Geometric Group Theory", a relatively young and very active research area. This election is done because it allows to go, within a full semester, from the basics of the theory to the description, with a good level of details and context, of some open problems that are currently being object of active research today.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
<td></td>
</tr>
</tbody>
</table>
# 34951 - NCA - Non-Commutative Algebra

## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Generalities about infinite groups** | 47h | Theory classes: 15h  
Self study: 32h |
| **Description:** |  | The free group: basic definitions.  
Presentations: generators and relations.  
Short exact sequences, direct and semidirect products.  
Free products, amalgams, HNN extensions.  
Thompson’s group as an example. |
| **The classical Dehn problems in group theory** | 25h | Theory classes: 8h  
Self study: 17h |
| **Description:** |  | Description of the three classical algorithmic problems in group theory: word, conjugacy and isomorphism problems.  
Resolution of the word and conjugacy problems in simple cases: abelian, free, free-like constructions, residually finite, etc.  
Examples of algorithmically unsolvable problems: word, membership, isomorphism problems, $F_2 \times F_2$. |
| **The free group** | 47h | Theory classes: 15h  
Self study: 32h |
| **Description:** |  | Stallings foldings and the lattice of subgroups of the free group.  
Membership, conjugacy, finite index, intersection of subgroups.  
Hall's theorem and residual properties of free groups. |
| **Cayley graphs** | 31h | Theory classes: 10h  
Self study: 21h |
| **Description:** |  | Cayley graph and the word metric in a group.  
Dehn function, examples; characterization of the solvability of the word problem via Dehn functions.  
Growth of a group, examples. Gromov theorem. |
34951 - NCA - Non-Commutative Algebra

Hyperbolic groups

<table>
<thead>
<tr>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td>Self study: 25h 30m</td>
</tr>
</tbody>
</table>

Description:
Definition of hyperbolic groups.
First properties, finite generation, centralizers.
Characterization of hyperbolic groups as those having linear Dehn function.

Qualification system

The student will have to develop a subject, first in term paper form, of about 15-20 pages, and also as a one to two hours lecture. The subject can be assigned by the teacher, or it can be picked by the student, among all topics in Geometric Group Theory of his interest.

Bibliography

Basic:


Complementary:

34952 - AG - Algebraic Geometry

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 725 - MA I - Department of Applied Mathematics I  
**Academic year:** 2015  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** JAUME AMOROS TORRENT  
**Others:** JAUME AMOROS TORRENT - A

### Opening hours

**Timetable:** TBA. You may contact the lecturer through e-mail.

### Prior skills

Aquaintance with mathematical computations, both by hand and with a computer, and mathematical reasoning, including proofs.

### Requirements

Basic abstract Algebra, Topology and Differential Geometry.

### Degree competences to which the subject contributes

#### Specific:
1. **RESEARCH.** Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.  
2. **CALCULUS.** Obtain (exact or approximate) solutions for these models with the available resources, including computational means.  
3. **CRITICAL ASSESSMENT.** Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

#### Transversal:
4. **SELF-DIRECTED LEARNING.** Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.  
5. **EFFICIENT ORAL AND WRITTEN COMMUNICATION.** Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.  
6. **THIRD LANGUAGE.** Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.  
7. **EFFECTIVE USE OF INFORMATION RESOURCES.** Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
Teaching methodology

Roughly 50% of the class time will be devoted to the master classes, in which the lecturer will discuss the course topics. The other half of the class time will be structured as a problem class, in which the students will solve in the blackboard problems from a proposed list, based on the course syllabus, and their solutions will be discussed by the class.

Learning objectives of the subject

The main objective of the course is to introduce the student to the Algebraic Geometry of affine and projective varieties, both algebraically over a field (Q, finite fields) and analytically over the real, and specially over the complex numbers. The course will be based on many examples, stressing the geometric interest of the subject. The topic of the final lectures will depend on the interests of the audience, with a view towards the assigned final projects of the students.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60h</td>
<td>127h 30m</td>
</tr>
<tr>
<td></td>
<td>32.00%</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Chapter 1: Algebraic equations</th>
<th>Learning time: 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study: 9h</td>
</tr>
</tbody>
</table>

**Description:**
Introduction: how systems of algebraic equations determine ideals in the ring of functions and, in the case of equations over the real or complex numbers, its solutions form manifolds with a given dimension and singularities in their closure.

<table>
<thead>
<tr>
<th>Chapter 2: Algebraic varieties</th>
<th>Learning time: 13h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study: 7h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Chapter 3: Projective varieties</th>
<th>Learning time: 9h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 5h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Chapter 4: Maps and morphisms</th>
<th>Learning time: 13h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study: 7h</td>
</tr>
</tbody>
</table>

**Description:**
Tangent spaces. Nonsingular points. Smooth maps. Global topology of varieties: fundamental class, degree of morphisms, intersection numbers. Applications: determinantal varieties, grassmanians, parametrizing varieties...
34952 - AG - Algebraic Geometry

**Chapter 6: Sheaves**

<table>
<thead>
<tr>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>

**Description:**
Sheaves on a paracompact topological space, cohomology. Coherent sheaves on an algebraic variety: the canonical and hyperplane section sheaves, Riemann-Roch for curves. The Dolbeault complex over a complex analytic manifold: Hodge theory.

**Chapter 7: Final projects**

<table>
<thead>
<tr>
<th>Learning time: 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Self study: 8h</td>
</tr>
</tbody>
</table>

**Description:**
The topics of the final projects made by course students, explained by themselves and by the course lecturer.

**Qualification system**

Students who solve enough problems on the blackboard in the problem class pass the course. If they want to improve their grade from pass towards top score they will be assigned a final project, which will be to study and lecture on an additional topic at the end of the course.

Students who have not participated enough in the problem class, or still want to improve on their grade after problem class and additional lecture, will have to take a final exam of approximately 4 hours.

**Regulations for carrying out activities**

The problem list for participation in problem class will be published at the start of every course unit. Students will prepare these problems at home.

The topics for optional, grade increasing lectures at the end of the course will be proposed around Easter. Students will prepare these lectures at home.

Students who take the final exam will have to do so without any notes, books or material whatsoever.
34952 - AG - Algebraic Geometry

Bibliography

Basic:
- Reid, Miles. Undergraduate commutative algebra. Cambridge U.P.,
- Reid, Miles. Undergraduate algebraic geometry. Cambridge U.P.,
- Griffiths, Phillip ; Harris, Joseph. Principles of algebraic geometry. John Wiley and Sons,

Complementary:
- Voisin, Claire. Hodge theory and complex algebraic geometry 1. Cambridge U.P.,
- Beauville, A.. Complex algebraic surfaces. Cambridge U.P.,
34953 - NT - Number Theory

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
726 - MA II - Department of Applied Mathematics II
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: JORDI GUARDIA RUBIES
Others: JORDI GUARDIA RUBIES - A

Prior skills
Basic knowledge of algebraic structures: groups, rings and fields.

Requirements
Basic material covered in any standard course on group theory and Galois theory. Although it is not strictly necessary, any background on algebraic curves, elliptic curves and basic number theory. But the course will be completely self-contained.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34953 - NT - Number Theory

Teaching methodology

Most of the lectures will take place on the blackboard, explaining carefully the contents of the course and providing as much explicit examples, exercises and applications as possible. The students will be encouraged to consult suitable references and to discuss between them and with the professor in order to achieve a good understanding of the material.

Learning objectives of the subject

1) Algebraic number theory.
2) Arithmetic of elliptic curves

The material covered in this course interplays with topics of commutative algebra (Dedekind rings, discrete valuation rings and prime ideals), non-commutative algebra (group rings, quaternion algebras, associative algebras) and algebraic geometry (spectrum of a ring, algebraic curves, Riemann surfaces).

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>

Content

<table>
<thead>
<tr>
<th>Algebraic Number Theory</th>
<th>Learning time: 93h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 30h</td>
</tr>
<tr>
<td></td>
<td>Self study: 63h 45m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elliptic Curves</th>
<th>Learning time: 93h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 30h</td>
</tr>
<tr>
<td></td>
<td>Self study: 63h 45m</td>
</tr>
</tbody>
</table>

Qualification system

There will be no exams. The qualification will be based on:
1) Active participation of the student during the course,
2) Resolution of exercises suggested in class and,
3) Elaboration of a document in which the student develops in more detail and depth some of the material of the course.

Regulations for carrying out activities

Solved exercises and works must be delivered on the last day of the course.
34953 - NT - Number Theory

Bibliography

Basic:


Others resources:

Computer material

SAGE

Mathematical Software
34954 - CC - Codes and Cryptography

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
726 - MA II - Department of Applied Mathematics II
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5

Teaching languages: English

Teaching staff
Coordinator: MARIA PAZ MORILLO BOSCH
Others:
SIMEON MICHAEL BALL - A
JAVIER HERRANZ SOTOCA - A
MARIA PAZ MORILLO BOSCH - A
JORGE LUIS VILLAR SANTOS - A

Prior skills
Basic probability, basic number theory and linear algebra

Requirements
Undergraduate mathematics

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
This course aims to give a solid understanding of the uses of mathematics in Information technologies and modern communications. The course focuses on the reliable and efficient transmission and storage of the information. Both the mathematical foundations and the description of the most important cryptographic protocols and coding systems are given in the course.

Teaching methodology

The course is divided in two parts: codes and cryptography. Each part consists of 26 h of ordinary classes, including theory and problem sessions.

Learning objectives of the subject

Total learning time: 187h 30m

Hours large group: 60h 32.00%
Self study: 127h 30m 68.00%

Study load
### Introduction

**Learning time:** 6h 15m  
Theory classes: 2h  
Self study: 4h 15m

**Description:**  
The problem of communication. Information theory, Coding theory and Cryptographic theory

### Information and Entropy

**Learning time:** 18h 45m  
Theory classes: 6h  
Self study: 12h 45m

**Description:**  
Uncertainty or information. Entropy. Mutual information

### Source codes without memory

**Learning time:** 12h 30m  
Theory classes: 4h  
Self study: 8h 30m

**Description:**  

### Channel coding

**Learning time:** 18h 45m  
Theory classes: 6h  
Self study: 12h 45m

**Description:**  
Discrete channels without memory. Symmetric channels. Shannon's theorem.

### Block codes

**Learning time:** 18h 45m  
Theory classes: 6h  
Self study: 12h 45m

**Description:**  
### 34954 - CC - Codes and Cryptography

**Cyclic codes**

<table>
<thead>
<tr>
<th>Learning time: 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Self study : 12h 45m</td>
</tr>
</tbody>
</table>

**Description:**

---

### Introduction to modern cryptography

<table>
<thead>
<tr>
<th>Learning time: 15h 37m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Self study : 10h 37m</td>
</tr>
</tbody>
</table>

**Description:**

---

### Symmetric key cryptography

<table>
<thead>
<tr>
<th>Learning time: 15h 38m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Self study : 10h 38m</td>
</tr>
</tbody>
</table>

**Description:**

---

### Public key encryption

<table>
<thead>
<tr>
<th>Learning time: 15h 37m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Self study : 10h 37m</td>
</tr>
</tbody>
</table>

**Description:**

---

### Digital signatures

<table>
<thead>
<tr>
<th>Learning time: 15h 38m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Self study : 10h 38m</td>
</tr>
</tbody>
</table>

**Description:**
Security definitions. RSA and Schnorr signatures.
Exam of coding part (50%) and exam of crypto part (50%). If the average is less than 5 out of 10, there is a chance to pass the subject in a final exam.

Qualification system
Exam of coding part (50%) and exam of crypto part (50%). If the average is less than 5 out of 10, there is a chance to pass the subject in a final exam.

Regulations for carrying out activities
All the subjects are important. To pass the course it is required to fulfill all the items.

<table>
<thead>
<tr>
<th>Proofs of knowledge and other cryptographic protocols</th>
<th>Learning time: 15h 37m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td></td>
<td>Self study : 10h 37m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>Ring signatures. Distributed signatures. Identity</td>
<td></td>
</tr>
<tr>
<td>and attribute based protocols.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiparty computation</th>
<th>Learning time: 15h 38m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td></td>
<td>Self study : 10h 38m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>Secret sharing schemes. Unconditionally and</td>
<td></td>
</tr>
<tr>
<td>computationally secure multiparty computation.</td>
<td></td>
</tr>
</tbody>
</table>
34954 - CC - Codes and Cryptography

Bibliography

Basic:


Complementary:


34955 - COMB - Combinatorics

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
726 - MA II - Department of Applied Mathematics II

Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: MARCOS NOY SERRANO
Others: MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

Prior skills
Basic calculus and linear algebra. Notions of probability.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology
There will be a lecture each week, followed by a problem session.

Learning objectives of the subject
34955 - COMB - Combinatorics

To use algebraic, probabilistic and analytic methods for studying combinatorial structures. The main topics of study are: partially ordered sets, extremal set theory, finite geometries, matroids, Ramsey theory and enumerative combinatorics.

<table>
<thead>
<tr>
<th>Study load</th>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 24h 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partially ordered sets</strong></td>
<td>3h</td>
</tr>
<tr>
<td><strong>Practical classes</strong>: 4h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Laboratory classes</strong>: 4h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Self study</strong>: 16h 40m</td>
<td>3h</td>
</tr>
</tbody>
</table>

**Description:**
Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 24h 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extremal set theory</strong></td>
<td>3h</td>
</tr>
<tr>
<td><strong>Theory classes</strong>: 4h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Laboratory classes</strong>: 4h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Self study</strong>: 16h 40m</td>
<td>3h</td>
</tr>
</tbody>
</table>

**Description:**
Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linear algebra methods in combinatorics</strong></td>
<td>3h</td>
</tr>
<tr>
<td><strong>Theory classes</strong>: 3h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Laboratory classes</strong>: 3h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Self study</strong>: 12h 30m</td>
<td>3h</td>
</tr>
</tbody>
</table>

**Description:**
The polynomial method and applications. Fisher's theorem. Equiangular lines, sets with few differences

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finite geometries</strong></td>
<td>3h</td>
</tr>
<tr>
<td><strong>Theory classes</strong>: 3h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Laboratory classes</strong>: 3h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Self study</strong>: 12h 30m</td>
<td>3h</td>
</tr>
</tbody>
</table>

**Description:**
### 34955 - COMB - Combinatorics

| **Matroids** | **Learning time:** 18h 30m  
| Theory classes: 3h  
| Laboratory classes: 3h  
| Self study: 12h 30m |

**Description:**
Axioms. Transversal matroids. Greedy algorithms. The Tutte polynomial

| **Probabilistic methods in combinatorics** | **Learning time:** 18h 30m  
| Theory classes: 3h  
| Laboratory classes: 3h  
| Self study: 12h 30m |

**Description:**
Permanents, transversals, hypergraph coloring. Monotone properties and threshold functions

| **Ramsey theory** | **Learning time:** 31h 40m  
| Theory classes: 5h  
| Laboratory classes: 5h  
| Self study: 21h 40m |

**Description:**
Theorems of Ramsey and Hales-Jewett. Theorems of Schur, Van der Waerden and Rado.

| **Enumerative combinatorics** | **Learning time:** 32h 30m  
| Theory classes: 5h  
| Laboratory classes: 5h  
| Self study: 22h 30m |

**Description:**
Symbolic and analytic methods. Symmetries and Pólya theory.

### Qualification system

Grading will be based on the solution of exercises. Eventually there will be a final examination.
Bibliography

Basic:


34956 - DG - Discrete and Algorithmic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 726 - MA II - Department of Applied Mathematics II
Academic year: 2015
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5 Teaching languages: English

Teaching staff

Coordinator: VERA SACRISTAN ADINOLFI
Others: VERA SACRISTAN ADINOLFI - A
RODRIGO IGNACIO SILVEIRA - A

Prior skills

- Elementary combinatorics.
- Elementary graph theory.
- Elementary algorithmics.
- Elementary data structures.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
Teaching methodology

Theory classes will be used to present and develop the contents of the course. Most of the topics will be presented by the instructors, but there can be some sessions devoted to students presentations.

There will be lists of problems, which will not contain solutions. Problems will be designed to help students deepen and mature their command of the concepts and techniques presented in class. Some problems will be solved in class, some will be left as homework. In the problem sessions, the goal will be to propose and analyze alternative strategies to solve each problem, and to show how the results presented in class are applied. Most of the problems solved in class will be presented by the students.

Learning objectives of the subject

Discrete, combinatorial and computational geometry are facets of a common body of knowledge that integrates fundamental elements from mathematics -mainly from algebra, topology and classical branches of geometry- with elements and problems from theoretical computer science and its applications.

The area focuses on the combinatorial and structural study of discrete geometric objects, as well as the design of algorithms to construct or analyze them. Among the objects studied, we can mention discrete sets of points, curves and manifolds, polytopes, convex bodies, packings, space decompositions, graphs, and geometric matroids.

By the end of the course, students should:
- Be able to recognize and formally express discrete geometric problems.
- Be able to discretize geometric problems, when possible.
- Be able to apply combinatorial techniques, as well as data structures and algorithms to discrete geometric problems.
- Be able to search the bibliography, and to understand the scientific literature on the subject.
- Be aware of the wide range of fields and problems to which discrete geometry results apply.
- Be aware of the most commonly used software in the field.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m 68.00%</td>
</tr>
</tbody>
</table>
### Content

<table>
<thead>
<tr>
<th><strong>Preliminaries</strong></th>
<th><strong>Learning time:</strong> 12h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Computational complexity. Data structures. Representation of geometric objects.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Convexity</strong></th>
<th><strong>Learning time:</strong> 19h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Convex hull computation. Linear programming in low dimensions.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Decompositions and arrangements</strong></th>
<th><strong>Learning time:</strong> 31h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Proximity Structures</strong></th>
<th><strong>Learning time:</strong> 31h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Proximity problems. Voronoi diagram, Delaunay triangulation. Shape reconstruction.</td>
<td></td>
</tr>
</tbody>
</table>
### Polytopes and Subdivisions of Point Sets

**Description:**
Homogeneous coordinates. Polytopes: faces and boundary structure; examples; operations on polytopes (polarity, products, etc.). Point sets: subdivisions and triangulations (including Delaunay and Voronoi).

**Learning time:** 38h  
Theory classes: 10h  
Laboratory classes: 3h  
Self study: 25h

### Lattice Geometry

**Description:**
Examples of lattices. Ehrhart's Theorem on integer points in polytopes. Brion's Theorem.

**Learning time:** 24h  
Theory classes: 6h  
Laboratory classes: 2h  
Self study: 16h

### Symmetry

**Description:**
Orbifolds and the Magic Theorem on symmetry groups in the plane. Exploitation of symmetry in linear optimization.

**Learning time:** 23h  
Theory classes: 6h  
Practical classes: 1h  
Self study: 16h

### Software

**Description:**
Polymake, Curved Spaces, etc.

**Learning time:** 9h  
Laboratory classes: 2h  
Self study: 7h
In general, there will be two or more exams during class hours, to be announced in advance. If so announced, students will also obtain marks by turning in their solutions to problems from the problem sets, and possibly presenting them at the blackboard.

In the case of a very small group, some exams may be replaced by personal work.

The exams and marks for the turned-in work will combine for the final qualification.
Bibliography

Basic:


Complementary:


Others resources:

Audiovisual material


Not knot [Enregistrament vídeo] / directed by Charlie Gunn and Delle Maxwell ; [written by David Epstein ... [et al.]]. Minnesota : Geometry Center, University of Minnesota, 1991

Flatland [Enregistrament vídeo]: a journey of many dimensions / written by Seth Caplan, Dano Johnson, Jeffrey Travis ; directed by Jeffrey Travis, Dano Johnson. [S.I.] : Flat World Productions, cop. 2007
34957 - GT - Graph Theory

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: ORIOL SERRA ALBO
Others:
ANNA LLADO SANCHEZ - A
MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

Prior skills
Elementary Calculus and Linear Algebra; basic notions and abilities in combinatorics and probability.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology
Sessions of presentation of material alternate with sessions with student presentations of problems and specific topics. The active participation of students is a requirement for the evaluation of the course.

Learning objectives of the subject
34957 - GT - Graph Theory

Application of spectral techniques to the study of graphs.
Application of the probabilistic method.
Properties of almost all graphs.
Properties of Cayley and vertex symmetric graphs.
Graphs on surfaces.
Minors.

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td></td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

| Spectral techniques in Graph Theory | Learning time: 1h  
Theory classes: 1h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td></td>
</tr>
</tbody>
</table>

| Symmetries in graphs               | Learning time: 1h  
Theory classes: 1h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minors and treewidth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Degree competences to which the content contributes:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Graphs on surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Degree competences to which the content contributes:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Graph homomorphisms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Degree competences to which the content contributes:</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Random graphs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Degree competences to which the content contributes:</strong></td>
</tr>
</tbody>
</table>
The evaluation of the course is based on the weekly work on problems proposed in the presentation sessions. There will be a final comprehensive exam based on the problem sessions during the course.

**Qualification system**

The active participation in the course is a requirement for the evaluation of the final exam.

**Bibliography**

**Basic:**

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Prior skills
- Good knowledge of Calculus techniques, including integral theorems and basic Complex Variable methods.
- Elementary solution of PDEs and ODEs.
- Some experience on simple cases of mathematical modelling, especially in classical physics (gravitation, heat conduction, mechanics or electromagnetism).

Teaching staff
Coordinator: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ
Others:
JAIME HARO CASES - A
JOAQUIM SERRA MONTOLÍ - A
JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ - A
The course will provide a general overview on the use of partial differential equations (PDE) and boundary value problems to construct mathematical models of real phenomena. By the end of the course the student should have acquired:

* a knowledge of the problems that can be modelled with PDE's.
* intuitive and physical interpretations of the terms that appear on PDE's.

**Teaching methodology**

Lectures will contain the main contents of the course, but the students will also be asked to make presentations of additional material in seminar sessions. Problem solution will also be asked.

**Learning objectives of the subject**

The course will provide a general overview on the use of partial differential equations (PDE) and boundary value problems to construct mathematical models of real phenomena. By the end of the course the student should have acquired:

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
<th>Self study: 127h 30m 68.00%</th>
</tr>
</thead>
</table>

Lectures will contain the main contents of the course, but the students will also be asked to make presentations of additional material in seminar sessions. Problem solution will also be asked.
### Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Heat conduction and diffusion</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Potentials in physics and technology</td>
<td></td>
</tr>
<tr>
<td>Transients in continuous media</td>
<td></td>
</tr>
<tr>
<td>Population dynamics</td>
<td></td>
</tr>
<tr>
<td>Equations of distributions of particles</td>
<td></td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td></td>
</tr>
<tr>
<td>Theory classes: 12h</td>
<td></td>
</tr>
<tr>
<td>Self study : 25h 30m</td>
<td></td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td></td>
</tr>
<tr>
<td>Theory classes: 12h</td>
<td></td>
</tr>
<tr>
<td>Practical classes: 25h 30m</td>
<td></td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td></td>
</tr>
<tr>
<td>Theory classes: 12h</td>
<td></td>
</tr>
<tr>
<td>Practical classes: 25h 30m</td>
<td></td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td></td>
</tr>
<tr>
<td>Theory classes: 12h</td>
<td></td>
</tr>
<tr>
<td>Practical classes: 25h 30m</td>
<td></td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td></td>
</tr>
<tr>
<td>Theory classes: 12h</td>
<td></td>
</tr>
<tr>
<td>Practical classes: 25h 30m</td>
<td></td>
</tr>
</tbody>
</table>

### Qualification system

Attendance to lectures, presentation of additional materials and problem solving will be the basis of a qualification up to a certain level. A higher mark will require a written exam.
Bibliography

Basic:


Complementary:


34959 - CM - Computational Mechanics

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 727 - MA III - Department of Applied Mathematics III  
**Academic year:** 2015  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** JOSE JAVIER MUÑOZ ROMERO  
**Others:** JOSE JAVIER MUÑOZ ROMERO - A

### Prior skills

- Basic knowledge of numerical methods  
- Basic knowledge of partial differential equations

### Degree competences to which the subject contributes

**Specific:**

1. **RESEARCH.** Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.

2. **MODELLING.** Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.

3. **CALCULUS.** Obtain (exact or approximate) solutions for these models with the available resources, including computational means.

4. **CRITICAL ASSESSMENT.** Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

**Transversal:**

5. **SELF-DIRECTED LEARNING.** Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

6. **EFFICIENT ORAL AND WRITTEN COMMUNICATION.** Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.

7. **THIRD LANGUAGE.** Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

8. **TEAMWORK.** Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.

9. **EFFECTIVE USE OF INFORMATION RESOURCES.** Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

### Teaching methodology

Three elements will be combined: theory classes, where the main concepts will be presented; practical classes in the computer room, with emphasis on the computational aspects; and lists of problems. Students will work on these problems individually or in pairs.
The main objective is to provide a general perspective of the broad field of computational mechanics, covering both the modelling and the computational aspects. A broad range of problems is addressed: solids, fluids and fluid-solid interaction; linear and nonlinear models; static and dynamic problems. By the end of the course, the students should:

- Be able to choose the appropriate type of model for a specific simulation
- Be familiar with the mathematical objects (mainly tensors) used in computational mechanics
- Be aware of the different level of complexity of various problems (e.g. linear vs. nonlinear, static vs. dynamic).

<table>
<thead>
<tr>
<th>Study load</th>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
<td></td>
</tr>
</tbody>
</table>
### Content

#### CONTINUUM MECHANICS

**Description:**

**Learning time:** 31h 15m
- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m

#### COMPUTATIONAL ELASTICITY

**Description:**

**Learning time:** 31h 15m
- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m

#### COMPUTATIONAL DYNAMICS

**Description:**

**Learning time:** 31h 15m
- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m
### COMPUTATIONAL PLASTICITY

**Learning time:** 31h 15m  
**Theory classes:** 8h  
**Practical classes:** 2h  
**Self study:** 21h 15m

**Description:**  
Basic concepts and motivation. One-dimensional plasticity: elastic and plastic strains; elastoplastic constitutive equation; hardening. Multi-dimensional plasticity: stress and strain invariants; yield surface; plastic flow. Numerical time-integration of the constitutive equation: elastic prediction and plastic correction; iterative methods for the plastic correction. Applications.

### COMPUTATIONAL FLUID DYNAMICS

**Learning time:** 31h 15m  
**Theory classes:** 8h  
**Practical classes:** 2h  
**Self study:** 21h 15m

**Description:**  

### COMPUTATIONAL METHODS FOR WAVE PROBLEMS

**Learning time:** 31h 15m  
**Theory classes:** 8h  
**Practical classes:** 2h  
**Self study:** 21h 15m

**Description:**  
Basic concepts and motivation.  

### Qualification system

Exam and assigned problems.
Bibliography

Basic:


Complementary:


34960 - MMB - Mathematical Models in Biology

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5  Teaching languages: English

Teaching staff
Coordinator: ANTONI GUILLAMON GRABOLOSA
Others: JESUS FERNANDEZ SANCHEZ - A
ANTONI GUILLAMON GRABOLOSA - A
GEMMA HUGUET CASADES - A

Prior skills
* Proficiency in undergraduate mathematics: calculus, algebra, probability and statistics.
* Ability to perform basic operations in linear algebra: eigenvalues and eigenvectors, computation of determinants, rank of matrices...
* Ability to analyze and solve linear differential equations and discuss the stability of simple vector fields.
* Interest towards biological applications of mathematics and/or previous working experience.

Requirements
* Basic knowledge of undergraduate mathematics: calculus, ordinary differential equations, linear algebra, probability and statistics.
* First course in ordinary differential equations: linear differential equations, qualitative and stability theory and numerical simulation.
* Basic knowledge of computer programming for scientific purposes.
* Courses and all the bibliography will be in English.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
34960 - MMB - Mathematical Models in Biology

7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology

The course will be structured in five blocks each consisting of a brief introduction through theoretical lectures, the development of a short project in groups and wrap-up sessions with oral presentations, discussion and complementary lectures.

The central part intended to develop the short project will held at the computer lab. The SAGE computing environment will be used, with interfaces to Python, R and C if necessary.

Learning objectives of the subject

This course is an introduction to the most common mathematical models in biology: in populations dynamics, ecology, physiology, sequence analysis and phylogenetics. At the end of the course the student should be able to:

* Understand and discuss basic models of dynamical systems of biological origin, in terms of the parameters.
* Model simple phenomena, analyze them (numerically and/or analytically) and understand the effect of parameters.
* Understand the diversity of mechanisms and the different levels of modelization of physiological activity.
* Obtain and analyze genomic sequences of real biological species and databases containing them.
* Use computer software for gene prediction, alignment and phylogenetic reconstruction.
* Understand different gene prediction, alignment and phylogenetic reconstruction methods.
* Compare the predictions given by the models with real data.
* Communicate results in interdisciplinary teams.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
# 34960 - MMB - Mathematical Models in Biology

## Content

### Mathematical models in Genomics

<table>
<thead>
<tr>
<th>Learning time: 75h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td>Laboratory classes: 12h</td>
</tr>
<tr>
<td>Self study: 51h</td>
</tr>
</tbody>
</table>

**Description:**
1. Brief introduction to genomics (genome, gen structure, genetic code...). Genome databases online.
4. Multiple sequence alignment: dynamical programming, tropical arithmetics and Pair-HMMs

### Mathematical Models in Neurophysiology

<table>
<thead>
<tr>
<th>Learning time: 56h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 9h</td>
</tr>
<tr>
<td>Laboratory classes: 9h</td>
</tr>
<tr>
<td>Self study: 38h 15m</td>
</tr>
</tbody>
</table>

**Description:**
1) Membrane biophysics.
2) Excitability and Action potentials: The Hodgkin-Huxley model, the Morris-Lecar model, integrate & fire models.
3) Bursting oscillations.
4) Synaptic transmission and dynamics.

### Models of Population Dynamics

<table>
<thead>
<tr>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Laboratory classes: 6h</td>
</tr>
<tr>
<td>Self study: 25h 30m</td>
</tr>
</tbody>
</table>

**Description:**
2. One-dimensional discrete models. Chaos in biological systems.
3. Paradigms of population dynamics in current research.
34960 - MMB - Mathematical Models in Biology

**Biological networks**

<table>
<thead>
<tr>
<th><strong>Learning time:</strong> 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Laboratory classes: 3h</td>
</tr>
<tr>
<td>Self study: 12h 45m</td>
</tr>
</tbody>
</table>

**Description:**
2. Networks of neurons.

**Qualification system**

50%: Each of the five blocks will give a part (10%) of the qualification, based on the performance on the short-projects.
20%: Overall evaluation of the participation, interest and proficiency evinced along the course.
30%: Final exam aiming at validating the acquisition of the most basic concepts of each block.
Bibliography

Basic:


Complementary:


Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: MARIA TERESA MARTINEZ-SEARA ALONSO
Others:
AMADEU DELSHAMS I VALDES - A
MARIA TERESA MARTINEZ-SEARA ALONSO - A

Opening hours

Timetable: Make an appointment by email

Prior skills

Basic knowledge of calculus, algebra and differential equations. Some basic ideas of local dynamical systems.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Teaching methodology

We don't distinguish theoretical and practical classes. Some results about modern theory in Dynamical systems are presented in class. The main idea is to give basic knowledge and useful tools in the study of a dynamical system from both quantitative and qualitative points of view. We will stress the relation between different kind of systems and we will mainly focus in the use of perturbatives techniques to study a dynamical system globally.

Learning objectives of the subject

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
### Content

| Invariant objects in Dynamical Systems | Learning time: 10h  
| Other activities: 10h |
|---|---|
| **Description:**  
Continuous and discrete Dynamical Systems.  
Poincaré map.  
Local behaviour of hyperbolic invariant objects.  
Invariant manifolds. Central manifold. Local bifurcations. | |

| Perturbation theory in Dynamical Systems | Learning time: 10h  
| Other activities: 10h |
|---|---|
| **Description:**  
Clasic perturbation theory. Perturbed homoclinic orbits in the plane. Melnikov method. | |

| Discrete Dynamical Systems | Learning time: 10h  
| Other activities: 10h |
|---|---|
| **Description:**  

| Homoclinic points and chaotic Dynamics | Learning time: 10h  
| Other activities: 10h |
|---|---|
| **Description:**  
Homoclinic points and bifurcations. Hyperbolic sets and transversal homoclinic points. Dynamical systems with chaotic dynamics. Newhouse phenomenon. | |
### Normal forms

**Learning time:** 10h  
Other activities: 10h

**Description:**  

### Normal forms: its application to stability in Dynamical Systems

**Learning time:** 10h  
Other activities: 10h

**Description:**  

### Introduction to non-smooth systems

**Learning time:** 4h  
Theory classes: 4h

**Description:**  
We will provide several examples of non-smooth systems and give the basic theory for them.

### Qualification system

The students have to do some problems and a research work. On the other hand they will attend the winter courses "Recent trends in non-linear science" and produce a document about them.

### Regulations for carrying out activities

There are no exams.
Bibliography

Basic:


34962 - HS - Hamiltonian Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: MARIA TERESA MARTINEZ-SEARA ALONSO
Others: MARCEL GUARDIA MUNARRIZ - A
MARIA TERESA MARTINEZ-SEARA ALONSO - A

Prior skills
Knowledge of calculus, algebra and ordinary differential equations.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology
Standard exposition in front of the blackboard, resolution of exercises, completion of a project and attendance to the JISD summer school http://www.ma1.upc.edu/recerca/jisd
34962 - HS - Hamiltonian Systems

Learning objectives of the subject

To comprehend the basic foundations of the theory of Hamiltonian systems, and to understand its applications to the Celestial Mechanics and other fields.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

| **Hamiltonian formalism** | **Learning time:** 26h  
Theory classes: 8h  
Self study: 18h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Hamiltonian dynamical systems: symplectic maps, symplectic manifolds. Linear Hamiltonian systems and their application to the study of stability of equilibrium points.</td>
<td></td>
</tr>
</tbody>
</table>

| **Hamiltonian and Lagrangian systems** | **Learning time:** 13h  
Theory classes: 4h  
Self study: 9h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Lagrangian systems. Configuration manifold, tangent and cotangent bundles. Systems with symmetries, Noether theorem. Principle of minimal action.</td>
<td></td>
</tr>
</tbody>
</table>

| **Integrable and quasi-integrable Hamiltonian systems** | **Learning time:** 13h  
Theory classes: 4h  
Self study: 9h |
|-------------------------------------------------------|-------------------------|

| **Invariant objects of dynamical systems** | **Learning time:** 13h  
Theory classes: 4h  
Self study: 9h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Continuous and discrete dynamical systems, Poincaré map. Local structure of hyperbolic invariant objects: invariant manifolds. Center manifold. Local bifurcations.</td>
<td></td>
</tr>
</tbody>
</table>
# 34962 - HS - Hamiltonian Systems

## Normal forms

**Description:**

**Learning time:** 13h
- Theory classes: 4h
- Self study: 9h

## Stability of dynamical systems and Hamiltonian systems

**Description:**

**Learning time:** 11h
- Practical classes: 2h
- Self study: 9h

## Applications to celestial mechanics

**Description:**

**Learning time:** 8h
- Theory classes: 4h
- Laboratory classes: 4h

## - Interactions between Dynamical Systems and Partial Differential Equations

**Description:**
Summer School and Research workshop on topics between Dynamical Systems and Partial Differential Equations

**Learning time:** 49h 30m
- Theory classes: 12h
- Self study: 37h 30m
Planning of activities

**JISD summer school**

**Description:**
Attendance to the JISD summer school http://www.ma1.upc.edu/recerca/jisd

**Specific objectives:**
To learn from outstanding researchers a view of the state of the art in several research topics, interacting with students of the rest of Spain and of the World.

Qualification system

The students have to do some problems and a research work. Moreover, they will attend the JISD and produce a document about them.

Bibliography

**Basic:**


**Others resources:**

**Hyperlink**

**Grup de sistemes dinàmics**

https://recerca.upc.edu/sd

pàgina web del Grup de Sistemes Dinàmics de la UPC on es descriuen diversos projectes i els investigadors que hi treballen així com diverses activitats relacionades
34963 - ACPDE - Advanced Course in Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5 Teaching languages: English

Teaching staff

Coordinator: ALBERT MAS BLESA
Others: MARIA DEL MAR GONZALEZ NOGUERAS - A
ALBERT MAS BLESA - A

Prior skills

Basic knowledge of Partial Differential Equations.
Basic knowledge of Mathematical Analysis (undergraduate level).

Requirements

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.

Degree competences to which the subject contributes

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34963 - ACPDE - Advanced Course in Partial Differential Equations

Teaching methodology

Classes will combine theoretical aspects and proofs with resolution of concrete problems and exercises. Further reading from the bibliography will be given often.

Learning objectives of the subject

Understand the classical methods to solve the Laplace, heat, and wave equations. Understand the role of Sobolev norms and compact embeddings to solve PDEs and find spectral decompositions. Learn the main methods available to solve nonlinear PDEs, through simple cases.

Study load

| Total learning time: 187h 30m | Hours large group: 60h | 32.00% |
| Self study: 127h 30m | | 68.00% |
# 34963 - ACPDE - Advanced Course in Partial Differential Equations

## Content

<table>
<thead>
<tr>
<th><strong>Classical methods for the Poisson and heat equations</strong></th>
<th><strong>Learning time:</strong> 47h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study : 32h</td>
</tr>
</tbody>
</table>

**Description:**
Maximum principles and Green's functions for the Poisson and heat equations.

<table>
<thead>
<tr>
<th><strong>Sobolev spaces and variational methods</strong></th>
<th><strong>Learning time:</strong> 47h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study : 32h</td>
</tr>
</tbody>
</table>

**Description:**
Basic properties of Sobolev spaces. Weak or variational formulation of boundary problems for linear elliptic PDEs.

<table>
<thead>
<tr>
<th><strong>Evolution equations</strong></th>
<th><strong>Learning time:</strong> 46h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study : 31h 45m</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th><strong>Introduction to nonlinear PDEs</strong></th>
<th><strong>Learning time:</strong> 46h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study : 31h 45m</td>
</tr>
</tbody>
</table>

**Description:**

## Qualification system

The evaluation of the course is based:
- on the weekly resolution of problems proposed in class (15%);
- a midterm exam (35%);
- a final comprehensive exam (50%).
- eventually, there could be the possibility of a final project in order to improve the grade.
- the active participation during the course will be a requirement for the evaluation of the final exam.
Bibliography

Basic:

Complementary:
34964 - NMDS - Numerical Methods for Dynamical Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2015
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff

Coordinator: MARIA MERCEDES OLLE TORNER
Others: MARIA MERCEDES OLLE TORNER - A

Prior skills

Good knowledge of a programming language.

Requirements

Knowledge of theory of systems of differential equations, algebra, calculus and numerical analysis.

Degree competences to which the subject contributes

Specific:

2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34964 - NMDS - Numerical Methods for Dynamical Systems

**Teaching methodology**

Theoretical sessions (presence of the students is necessary) and weekly practical tutorized assignments.

**Learning objectives of the subject**

- To reach an advanced formation in using numerical methods applied to dynamical systems
- To carry out numerical simulations of particular examples
- To relate different aspects of the dynamics in order to have a global picture of the behavior of a given problem
- To learn different tools to analyse and deal with a problem
- Ability in programming algorithms designed to solve particular problems in dynamical systems

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
<th>Self study: 127h 30m 68.00%</th>
</tr>
</thead>
</table>
## Content

**Numerical (preliminary) tools for practical purposes:** integrators for ODE and graphical interfaces. Examples.  
**Learning time:** 4h  
Theory classes: 2h  
Practical classes: 2h

**Dynamical systems:** introduction, definitions. Continuous and discrete dynamical systems. Orbit generation. Numerical computation of Poincare maps. Examples.  
**Learning time:** 6h  
Theory classes: 3h  
Practical classes: 3h

**Computation and stability of fixed points. Vector fields and maps. Implementation and examples.**  
**Learning time:** 10h  
Theory classes: 5h  
Practical classes: 5h

**Computation and stability of periodic orbits. Implementation, continuation of families, bifurcations. Multiple shooting.**  
**Learning time:** 10h  
Theory classes: 5h  
Practical classes: 5h

**Computation of tori: representation, computation and continuation. Implementation and examples.**  
**Learning time:** 15h  
Theory classes: 7h 30m  
Practical classes: 7h 30m

**Analysis of bifurcations. Some examples.**  
**Learning time:** 15h  
Theory classes: 7h 30m  
Practical classes: 7h 30m

---

**Degree competences to which the content contributes:**
34964 - NMDS - Numerical Methods for Dynamical Systems

Qualification system

100% of the qualification will be obtained from the practical assignments done.

Regulations for carrying out activities

No rules, in principle.

Bibliography

Basic:


Particular articles related to the topics of the course and some notes from suitable web pages.
### Degree competences to which the subject contributes

**Specific:**
1. **RESEARCH.** Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. **MODELLING.** Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. **CALCULUS.** Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. **CRITICAL ASSESSMENT.** Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

**Transversal:**
5. **SELF-DIRECTED LEARNING.** Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. **EFFICIENT ORAL AND WRITTEN COMMUNICATION.** Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. **THIRD LANGUAGE.** Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. **TEAMWORK.** Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. **EFFECTIVE USE OF INFORMATION RESOURCES.** Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

### Teaching methodology

Lectures, practical work at computer room, exercises and home works.
Learning objectives of the subject

This course is an introduction to numerical methods for the solution of partial differential equations, with application to applied sciences, engineering and biosciences.

The course includes the theoretical basis of the Finite Element Method (FEM) for the solution of elliptic and parabolic equations, and an introduction to stabilization techniques for convection-dominated problems, the FEM for compressible flow problems, numerical methods for first-order conservation laws (Finite Volumes, Discontinuous Galerkin) and advanced discretization techniques (such as meshless methods, X-FEM or DG methods).

The course will include frontal lectures and exercises, as well as computer sessions aimed at introducing the bases of the programming of the numerical methods.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
### Content

<table>
<thead>
<tr>
<th>Basics of the Finite Element Method (FEM)</th>
<th>Learning time: 20h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Basics on the Finite Element Method (FEM) for elliptic and parabolic equations: strong and weak form, discretization, implementation, functional analysis tools, error bounds and convergence, time integration for parabolic equations. Introduction to error estimation and adaptivity.</td>
<td></td>
</tr>
<tr>
<td>Theory classes: 10h</td>
<td></td>
</tr>
<tr>
<td>Laboratory classes: 10h</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stabilization techniques for convection-dominated problems</th>
<th>Learning time: 8h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> FEM for convection-diffusion problems. Stabilization techniques for convection-dominated problems.</td>
<td></td>
</tr>
<tr>
<td>Theory classes: 4h</td>
<td></td>
</tr>
<tr>
<td>Laboratory classes: 4h</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FEM for incompressible flow problems</th>
<th>Learning time: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition. Introduction to the numerical solution of the incompressible Navier-Stokes equations: nonlinearity, convection domination, LBB condition, boundary layers.</td>
<td></td>
</tr>
<tr>
<td>Theory classes: 4h</td>
<td></td>
</tr>
<tr>
<td>Practical classes: 2h</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Numerical methods for 1st order conservation laws</th>
<th>Learning time: 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Problems modeled by 1st order conservation laws: Maxwell equations for electromagnetics, acoustics, Euler equations, etc. Introduction to the Finite Volumes (FV) method. Introduction to DG methods for 1st order conservation laws.</td>
<td></td>
</tr>
<tr>
<td>Theory classes: 4h</td>
<td></td>
</tr>
<tr>
<td>Laboratory classes: 6h</td>
<td></td>
</tr>
</tbody>
</table>
Introduction to advanced discretization techniques

Learning time: 16h
   Theory classes: 8h
   Laboratory classes: 8h

Description:
Introduction to some of the following advanced discretization techniques: meshless or particle methods, eXtended Finite Elements (X-FEM), Discontinuous Galerkin (DG) for elliptic problems and compressible flow problems.

Qualification system

Exams (50%) and continuous assessment (exercises, projects and/or oral presentations) (50%).

Bibliography

Basic:


Complementary:


