Guia Docent

14/15

Facultat de Matemàtiques i Estadística

Master in Advanced Mathematics and Mathematical Engineering

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat de Matemàtiques i Estadística
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Introduction

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Professional opportunities

Curriculum

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INTRODUCTION

As reflected in its name, the master degree in Advanced Mathematics and Mathematical Engineering (MAMME) has a dual academic and professional orientation. On the academic side, it provides the skills and techniques needed in scientific research in general and, more specifically, in mathematical research. On the professional side, the goal is to provide the students with an advanced background to work in interdisciplinary teams, in cooperation with engineers, physicists, biologists, economists, etc.

Students may choose to take subjects from other master’s degrees, up to a maximum of 22.5 credits. The subjects may be from the master’s degree in Mathematics taught at the University of Barcelona and the master’s degree in Statistics and Operations Research (MESIO). Subjects from other UPC master’s degrees may also be taken subject to the approval of the director of the MAMME.

The FME offers a double master’s degree with the Illinois Institute of Technology (IIT), USA. Students who take the double degree course, which lasts one and a half years, will be awarded the MAMME by the FME and a master’s degree in Applied Mathematics by the IIT. Applications must be submitted before 1 November in the first semester of the master’s degree. Students also have the option of carrying out their master’s theses at the IIT, under the supervision of one of the Institute’s lecturers.

This master’s degree has received the International Master’s Programme distinction (2013 call) awarded by the Government of Catalonia’s Agency for the Management of University and Research Grants (AGAUR).

Consult the list of candidates admitted

Pre-enrolment | Open
---|---
Starting | September
Duration | One academic year
ECTS credits | 60
Delivery | Face-to-face
Languages of instruction | English
Organised by | School of Mathematics and Statistics (FME)
Prospective students | Anyone with good abstract reasoning, interest in problem solving, strong work habits and a liking for mathematics.
Location | Facultat de Matemàtiques i Estadística (FME)
| Campus Diagonal Sud. Edifici U. C. Pau Gargallo, 5
| 08028 Barcelona
Prices | €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.
Website | [http://mamme.masters.upc.edu](http://mamme.masters.upc.edu)
E-mails | cap.estudis.matematiques.fme@upc.edu

Curriculum
<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>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>Codes and Cryptography</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>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>Hamiltonian Systems</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>Mathematical Models in Biology</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>
</tbody>
</table>

**COMPETENCIES**

On finishing the master's degree, graduates will be able to:

**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 UPC 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.

**PROFESSIONAL OPPORTUNITIES**

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.)
### General requirements

**Recommended background**

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.

### Admission criteria

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.

### Entry places

30

### Pre-enrolment

Pre-enrolment period open.

[How to pre-enrol](#)

### Candidates admitted

[Consult the list of candidates admitted](#)

### Enrolment

[How to enrol](#)
Program

Structure

The master duration is 60 ECTS (European Credit transfer System) credits, and is intended to be completed in one academic year. This comprises 45 ECTS in courses and a master thesis (15 ECTS).

Master courses are offered in five broad fields:
- Algebra and Geometry
- Discrete Mathematics and Algorithmics
- Modelling in Engineering and Biomedical Sciences
- Differential Equations
- Scientific Computing

In addition, up to half of the course credits (i.e. 22.5 ECTS) may be taken from other master courses. This offers an excellent opportunity of specialisation in a given field according to one’s preferences.

Study program

Students are required to take 45 ECTS credits in courses and to write a master thesis (15 ECTS). The whole master program is intended to be completed in one academic year (30 ECTS/semester).

Master courses are offered in five fields:

<table>
<thead>
<tr>
<th>Area</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Algebra and Geometry (30 ECTS)</td>
</tr>
<tr>
<td></td>
<td>Discrete Mathematics and Algorithmics (30 ECTS)</td>
</tr>
<tr>
<td>B</td>
<td>Modelling in Engineering and Biomedical Sciences (22.5 ECTS)</td>
</tr>
<tr>
<td></td>
<td>Differential Equations (22.5 ECTS)</td>
</tr>
<tr>
<td></td>
<td>Scientific Computing (15 ECTS)</td>
</tr>
</tbody>
</table>

For greater flexibility, two paths may be followed:
- Taking the 45 ECTS in master courses from any of the five fields above.
- Taking up to 22.5 ECTS in external courses offered by other master's degrees, postgraduate studies, advanced courses in research centres, etc. This allows specialisation in a given field according to preferences.
Courses

The following courses (7.5 ECTS each) will be offered the next academic year:

Course list for academic year 2014-2015

Field: Algebra and Geometry
- Commutative Algebra (Spring term)
- Differentiable Manifolds (Spring term)
- Number Theory (Autumn term)
- Non-Commutative Algebra (Autumn term)

Field: Discrete Mathematics and Algorithmics
- Codes and Cryptography (Autumn term)
- Combinatorics (Spring term)
- Discrete and Algorithmic Geometry (Autumn term)
- Graph Theory (Autumn term)

Field: Modelling in Engineering and Biomedical Sciences
- Mathematical Modelling with Partial Differential Equations (Autumn term)
- Computational Mechanics (Autumn term)
- Mathematical Models in Biology (Autumn term)

Field: Differential Equations
- Quantitative and Qualitative Methods in Dynamical Systems (Autumn term)
- Hamiltonian Systems (Spring term)
- Advanced course in Partial Differential Equations (Spring term)

Field: Scientific Computing
- Numerical Methods for Dynamical Systems (Spring term)
- Numerical Methods for Partial Differential Equations (Autumn term)

Timetable for academic year 2014-2015

Exams
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: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: FRANCESC D’ASSIS PLANAS VILANOVA
Others: FRANCESC D’ASSIS PLANAS VILANOVA - 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
34950 - CALG - Commutative Algebra

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>Total learning time: 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: 12h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings and ideals</td>
<td>Large group/Theory: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study : 9h 45m</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>It covers rings, ideals, radicals, extensions, and contractions.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 12h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules</td>
<td>Large group/Theory: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study : 9h 45m</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>General properties of modules. Tensor product.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings and modules of fractions</td>
<td>Large group/Theory: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Introduction to rings and modules of fractions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary decompostion</td>
<td>Large group/Theory: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Classical primary theory. First theorems.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integral dependence</td>
<td>Large group/Theory: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 12h</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Definition of integral dependence. Theorems of going-up and going-down.</td>
<td></td>
</tr>
</tbody>
</table>
| **Chain conditions** | **Learning time:** 18h  
Large group/Theory: 6h  
Self study : 12h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Chain conditions on sets, modules, rings.</td>
</tr>
</tbody>
</table>

| **Noetherian rings** | **Learning time:** 18h  
Large group/Theory: 6h  
Self study : 12h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>They play a central role in Commutative Algebra and Algebraic Geometry.</td>
</tr>
</tbody>
</table>

| **Artin rings** | **Learning time:** 18h  
Large group/Theory: 6h  
Self study : 12h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>A good examples of noetherian rings. In some sense the simpliest.</td>
</tr>
</tbody>
</table>

| **Discrete valuation rings** | **Learning time:** 18h  
Large group/Theory: 6h  
Self study : 12h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>The next case. Noetherian rings of dimension one.</td>
</tr>
</tbody>
</table>

| **Completions** | **Learning time:** 18h  
Large group/Theory: 6h  
Self study : 12h |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>To deal with topologies, completions, filtrations and graded rings.</td>
</tr>
</tbody>
</table>
34950 - CALG - Commutative Algebra

**Dimension theory**

<table>
<thead>
<tr>
<th>Learning time: 18h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large group/Theory: 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: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: JOSE BURILLO PUIG
Others: JOSE BURILLO PUIG - 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 extend 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>Theory classes: 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

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

<table>
<thead>
<tr>
<th>Hyperbolic groups</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large group/Theory: 12h</td>
</tr>
<tr>
<td></td>
<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:**

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: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5

Teaching languages: English

Teaching staff

Coordinator: JORDI GUÀRDIA I RÚBIES
Others: JOSEP GONZALEZ ROVIRA - A
         JORDI GUÀRDIA I RÚBIES - 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>Theory classes: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
<td></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) Ellaboration 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:

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:** 2014

**Degree:** MASTER 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:**
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.

**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.
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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.

### Study load

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

### 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.
# 34954 - CC - Codes and Cryptography

## Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Learning time:</strong> 6h 15m</td>
</tr>
<tr>
<td></td>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study : 4h 15m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>The problem of communication. Information theory, Coding theory and Cryptographic theory</td>
<td></td>
</tr>
</tbody>
</table>

| **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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Cyclic codes**                           | **18h 45m**            | **Learning time:** 18h 45m  
|                                            | **Theory classes:** 6h | Cyclic codes. Generator and control matrices. Factorization of $x^n-1$. Roots of a cyclic code. BCH codes. Primitive Reed-Solomon codes. Meggit's decoder. |
|                                            | **Self study:** 12h 45m |                                                                                                                                             |
| **Introduction to modern cryptography**    | **15h 37m**            | **Learning time:** 15h 37m  
|                                            | **Theory classes:** 5h | The setting: secure storage and symmetric key encryption. Turing machines and complexity classes. Security definitions. Adversarial models. Reductionist security proofs. |
|                                            | **Self study:** 10h 37m |                                                                                                                                             |
| **Symmetric key cryptography**             | **15h 38m**            | **Learning time:** 15h 38m  
|                                            | **Theory classes:** 5h | Symmetric key encryption. Pseudorandom generators. Block ciphers. Message authentication codes. |
|                                            | **Self study:** 10h 38m |                                                                                                                                             |
| **Public key encryption**                  | **15h 37m**            | **Learning time:** 15h 37m  
|                                            | **Self study:** 10h 37m |                                                                                                                                             |
| **Digital signatures**                     | **15h 38m**            | **Learning time:** 15h 38m  
|                                            | **Theory classes:** 5h | Security definitions. RSA and Schnorr signatures. |
|                                            | **Self study:** 10h 38m |                                                                                                                                             |
34954 - CC - Codes and Cryptography

**Proofs of knowledge and other cryptographic protocols**

**Learning time:** 15h 37m
- Theory classes: 5h
- Self study: 10h 37m

**Description:**
Ring signatures. Distributed signatures. Identity and attribute based protocols.

**Multiparty computation**

**Learning time:** 15h 38m
- Theory classes: 5h
- Self study: 10h 38m

**Description:**
Secret sharing schemes. Unconditionally and computationally secure multiparty computation.

**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.
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: 2014
Degree: MASTER 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:
SIMEON MICHAEL BALL - A
ANNA DE MIER VINUÉ - A
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.
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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.
34955 - COMB - Combinatorics

Learning objectives of the subject

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.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Theory classes:</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>
<tr>
<td>Content</td>
<td>Learning time</td>
<td>Learning time</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td><strong>Partially ordered sets</strong></td>
<td></td>
<td>24h 40m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Theory classes: 4h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Practical classes: 4h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study : 16h 40m</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Extremal set theory**                      |               | 24h 40m       |
|                                              |               | Theory classes: 4h |
|                                              |               | Practical classes: 4h |
|                                              |               | Self study : 16h 40m |
| **Description:**                             |               |               |
| Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado |               |               |

| **Linear algebra methods in combinatorics**  |               | 18h 30m       |
|                                              |               | Theory classes: 3h |
|                                              |               | Practical classes: 3h |
|                                              |               | Self study : 12h 30m |
| **Description:**                             |               |               |
| The polynomial method and applications. Fisher's theorem. Equiangular lines, sets with few differences |               |               |

| **Finite geometries**                        |               | 18h 30m       |
|                                              |               | Theory classes: 3h |
|                                              |               | Practical classes: 3h |
|                                              |               | Self study : 12h 30m |
| **Description:**                             |               |               |
### Matroids

**Learning time:** 18h 30m  
- Theory classes: 3h  
- Practical 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  
- Practical 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  
- Practical 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  
- Practical 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:** 2014  
**Degree:** MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).  
(Teaching unit Optional)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** JULIAN THORALF PFEIFLE  
**Others:**  
FERNANDO ALFREDO HURTADO DIAZ - A  
JULIAN THORALF PFEIFLE - 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.  
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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.
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.

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.

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

### Preliminaries

**Description:**
Computational complexity. Data structures. Representation of geometric objects.

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

### Convexity

**Description:**
Convex hull computation. Linear programming in low dimensions.

**Learning time:** 19h
- Theory classes: 4h
- Practical classes: 2h
- Self study: 13h

### Decompositions and arrangements

**Description:**

**Learning time:** 31h
- Theory classes: 7h
- Practical classes: 3h
- Self study: 21h

### Proximity Structures

**Description:**
Proximity problems. Voronoi diagram, Delaunay triangulation. Shape reconstruction.

**Learning time:** 31h
- Theory classes: 7h
- Practical classes: 3h
- Self study: 21h
### 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
- Practical 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
- Practical 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
- Medium group/Practical: 1h
- Self study: 16h

### Software

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

**Learning time:** 9h
- Laboratory classes: 2h
- Self study: 7h
34956 - DG - Discrete and Algorithmic Geometry

**Qualification system**

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.l.]: Flat World Productions, cop. 2007
# 34957 - GT - Graph Theory

<table>
<thead>
<tr>
<th><strong>Coordinating unit:</strong></th>
<th>200 - FME - School of Mathematics and Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teaching unit:</strong></td>
<td>743 - MA IV - Department of Applied Mathematics IV</td>
</tr>
<tr>
<td><strong>Academic year:</strong></td>
<td>2014</td>
</tr>
<tr>
<td><strong>Degree:</strong></td>
<td>MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)</td>
</tr>
<tr>
<td><strong>ECTS credits:</strong></td>
<td>7,5</td>
</tr>
<tr>
<td><strong>Teaching languages:</strong></td>
<td>English</td>
</tr>
</tbody>
</table>

## Teaching staff

- **Coordinator:** ORIOL SERRA ALBO
- **Others:** 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.
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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

Application of spectral techniques to the study of graphs.
34957 - GT - Graph Theory

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

<table>
<thead>
<tr>
<th>Study load</th>
<th>Theory classes:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time:</strong> 187h 30m</td>
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</tr>
<tr>
<td></td>
<td>32.00%</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
### Spectral techniques in Graph Theory

**Degree competences to which the content contributes:**

**Description:**

**Specific objectives:**

### Symmetries in graphs

**Degree competences to which the content contributes:**

### Minors and treewidth

**Degree competences to which the content contributes:**

### Graphs on surfaces

**Degree competences to which the content contributes:**

### Graph homomorphisms

**Degree competences to which the content contributes:**

### Random graphs

**Degree competences to which the content contributes:**

### Extremal Graph Theory

**Learning time:** 75h

- Theory classes: 24h 10m
- Practical classes: 24h 10m
- Assessment sessions: 3h
- Self study (distance learning): 23h 40m
Qualification system

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.

Regulations for carrying out activities

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

Bibliography

Basic:


34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

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).

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.
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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.
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.

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Theory classes: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</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>1 Heat conduction and diffusion</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2 Potentials in physics and technology</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 Transients in continuous media</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 25h 30m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 Population dynamics</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 25h 30m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5 Distributions of particles</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 25h 30m</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.
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

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: 2014
Degree: MASTER 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.
34959 - CM - Computational Mechanics

Learning objectives of the subject

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).

Study load

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

#### CONTINUUM MECHANICS

**Description:**

<table>
<thead>
<tr>
<th>Learning time: 31h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large group/Theory: 8h</td>
</tr>
<tr>
<td>Medium group/Practical: 2h</td>
</tr>
<tr>
<td>Self study: 21h 15m</td>
</tr>
</tbody>
</table>

#### COMPUTATIONAL ELASTICITY

**Description:**

<table>
<thead>
<tr>
<th>Learning time: 31h 15m</th>
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</thead>
<tbody>
<tr>
<td>Large group/Theory: 8h</td>
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<tr>
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</tr>
<tr>
<td>Self study: 21h 15m</td>
</tr>
</tbody>
</table>

#### COMPUTATIONAL DYNAMICS

**Description:**

<table>
<thead>
<tr>
<th>Learning time: 31h 15m</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Medium group/Practical: 2h</td>
</tr>
<tr>
<td>Self study: 21h 15m</td>
</tr>
</tbody>
</table>
Exam and assigned problems.
Bibliography

**Basic:**


**Complementary:**


# 34960 - MMB - Mathematical Models in Biology

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 726 - MA II - Department of Applied Mathematics II  
725 - MA I - Department of Applied Mathematics I  
**Academic year:** 2014  
**Degree:** MASTER 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  
Casanellas Rius, Marta  
Casanellas Rius, Marta

## 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
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.

### 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:

### Study load

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

## Content

<table>
<thead>
<tr>
<th>Models of Population Dynamics</th>
<th>Learning time: 37h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large group/Theory: 6h</td>
</tr>
<tr>
<td></td>
<td>Small group/Laboratory: 6h</td>
</tr>
<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
</tbody>
</table>

**Description:**

1. Differential equations models. Stability and Bifurcations. Applications to population dynamics.
2. One-dimensional discrete models. Chaos in biological systems.
3. Introduction to stochastic models. Branching processes
4. Simulation with SAGE

<table>
<thead>
<tr>
<th>Mathematical models in Genomics</th>
<th>Learning time: 75h</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Small group/Laboratory: 12h</td>
</tr>
<tr>
<td></td>
<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

<table>
<thead>
<tr>
<th>Mathematical Models in Neurophysiology</th>
<th>Learning time: 56h 15m</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Small group/Laboratory: 9h</td>
</tr>
<tr>
<td></td>
<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.
34960 - MMB - Mathematical Models in Biology

**Biological networks**

<table>
<thead>
<tr>
<th>Learning time: 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large group/Theory: 3h</td>
</tr>
<tr>
<td>Small group/Laboratory: 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:


34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2014
Degree: MASTER 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.
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 perturavives 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>Theory classes: 60h</th>
<th>Self study: 127h 30m</th>
</tr>
</thead>
<tbody>
<tr>
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<td>68.00%</td>
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### Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 20h</th>
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<tbody>
<tr>
<td><strong>-Invariant objects in Dynamical Systems</strong></td>
<td></td>
</tr>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>Continuous and discrete Dynamical Systems.</td>
<td></td>
</tr>
<tr>
<td>Poincaré map.</td>
<td></td>
</tr>
<tr>
<td>Local behaviour of hyperbolic invariant objects.</td>
<td></td>
</tr>
<tr>
<td>Invariant manifolds.</td>
<td></td>
</tr>
<tr>
<td>Central manifold.</td>
<td></td>
</tr>
<tr>
<td>Local bifurcations.</td>
<td></td>
</tr>
</tbody>
</table>

| **-Perturbation theory in Dynamical Systems**     |                   |
| Description:                                     |                   |
| Classic perturbation theory.                     |                   |
| Perturbed homoclinic orbits in the plane.         |                   |
| Melnikov method.                                 |                   |

| **Discrete Dynamical Systems**                    |                   |
| Description:                                     |                   |
| Discrete systems.                                 |                   |
| Denjoy theorem.                                   |                   |
| Generic properties.                               |                   |
| Sarkovskii theorem.                               |                   |

| **-Homoclinic points and chaotic Dynamics**       |                   |
| Description:                                     |                   |
| Homoclinic points and bifurcations.              |                   |
| Hyperbolic sets and transversal homoclinic points. |                   |
| Dynamical systems with chaotic dynamics.         |                   |
| Newhouse phenomenon.                             |                   |
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.

**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: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: AMADEU DELSHAMS I VALDES
Others: AMADEU DELSHAMS I VALDES - 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.
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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 exercices, completion of a project and/or attendance to the JISD summer school http://www.ma1.upc.edu/recerca/jisd

Learning objectives of the subject
34962 - HS - Hamiltonian Systems

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

<table>
<thead>
<tr>
<th>Study load</th>
<th>Theory classes:</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>
## Content

### Hamiltonian formalism

**Learning time:** 26h  
Theory classes: 4h  
Practical classes: 4h  
Self study: 18h

**Description:**  
Hamiltonian dynamical systems: symplectic maps, symplectic manifolds. Linear Hamiltonian systems and their application to the study of stability of equilibrium points.

### Hamiltonian and Lagrangian systems

**Learning time:** 13h  
Theory classes: 2h  
Practical classes: 2h  
Self study: 9h

**Description:**  

### Integrable and quasi-integrable Hamiltonian systems

**Learning time:** 13h  
Theory classes: 2h  
Practical classes: 2h  
Self study: 9h

**Description:**  

### Invariant objects of dynamical systems

**Learning time:** 13h  
Theory classes: 2h  
Practical classes: 2h  
Self study: 9h

**Description:**  
Continuous and discrete dynamical systems, Poincaré map. Local structure of hyperbolic invariant objects: invariant manifolds. Center manifold. Local bifurcations.
### Perturbation theory in dynamical systems

**Description:**
Classical perturbation theory. Perturbations of homoclinic orbits in the plane: Melnikov method.

**Learning time:** 13h
- Theory classes: 2h
- Practical classes: 2h
- Self study: 9h

### Homoclinic points and chaotic dynamics

**Description:**
Homoclinic points and bifurcations. Hyperbolic sets and transverse homoclinic points: systems with chaotic dynamics. Newhouse phenomenon.

**Learning time:** 13h
- Theory classes: 2h
- Practical classes: 2h
- Self study: 9h

### Normal forms

**Description:**

**Learning time:** 13h
- Theory classes: 2h
- Practical classes: 2h
- Self study: 9h

### Stability of dynamical systems and Hamiltonian systems

**Description:**

**Learning time:** 13h
- Theory classes: 2h
- Practical classes: 2h
- Self study: 9h
Planning of activities

**JISD summer school**

**Description:**
Attendance to the JISD summer school [http://www.ma1.upc.edu/recerca/jisd](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.
34962 - HS - Hamiltonian Systems

Bibliography

**Basic:**


**Others resources:**

**Hyperlink**

**Grup de sistemes dinàmics**

https://recerca.upc.edu/sd

página 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: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: MARIA DEL MAR GONZALEZ NOGUERAS
Others: MARIA DEL MAR GONZALEZ NOGUERAS - A
XAVIER ROS OTON - 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.
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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**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Theory classes:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60h</td>
<td>127h 30m</td>
</tr>
</tbody>
</table>

68.00% 32.00%
34963 - ACPDE - Advanced Course in Partial Differential Equations

Content

<table>
<thead>
<tr>
<th>Classical methods for the Poisson and heat equations</th>
<th>Learning time: 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>Sobolev spaces and variational methods</th>
<th>Learning time: 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>Evolution equations</th>
<th>Learning time: 46h 45m</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study: 31h 45m</td>
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</tbody>
</table>

Description:

<table>
<thead>
<tr>
<th>Introduction to nonlinear PDEs</th>
<th>Learning time: 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.
34963 - ACPDE - Advanced Course in Partial Differential Equations

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: 2014
Degree: MASTER 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
- 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>Theory classes: 60h 32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Theory classes:</th>
<th>Practical classes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical (preliminary) tools for practical purposes: integrators for ODE and graphical interfaces. Examples.</td>
<td>4h</td>
<td>2h</td>
<td>2h</td>
</tr>
<tr>
<td>Dynamical systems: introduction, definitions. Continuous and discrete dynamical systems. Orbit generation. Numerical computation of Poincare maps. Examples.</td>
<td>6h</td>
<td>3h</td>
<td>3h</td>
</tr>
<tr>
<td>Computation and stability of fixed points. Vector fields and maps. Implementation and examples.</td>
<td>10h</td>
<td>5h</td>
<td>5h</td>
</tr>
<tr>
<td>Computation and stability of periodic orbits. Implementation, continuation of families, bifurcations. Multiple shooting.</td>
<td>10h</td>
<td>5h</td>
<td>5h</td>
</tr>
<tr>
<td>Computation of tori: representation, computation and continuation. Implementation and examples.</td>
<td>15h</td>
<td>7h 30m</td>
<td>7h 30m</td>
</tr>
<tr>
<td>Analysis of bifurcations. Some examples.</td>
<td>15h</td>
<td>7h 30m</td>
<td>7h 30m</td>
</tr>
</tbody>
</table>

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.
34965 - NMPDE - Numerical Methods for Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 727 - MA III - Department of Applied Mathematics III
Academic year: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: MARCO DISCACCIATI
Others: MARCO DISCACCIATI - A

Prior skills

Basics on numerical methods, differential equations and calculus.

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 approximation of partial differential equations. The indicative content of the course is as follows:

- Introduction to partial differential equations and to the finite elements method.
- Mathematical background: distributions, Sobolev spaces and weak formulations.
- Finite elements for elliptic problems: weak formulation with different types of boundary conditions; well-posedness of the variation formulation (the Lax-Milgram lemma); set up, analysis and error estimates for the finite elements Galerkin approximation.
- Finite element approximation of the Navier-Stokes equations for incompressible flows.
- Introduction to domain decomposition methods.

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

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Theory classes:</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>Introduction to partial differential equations and basics of functional analysis</th>
<th><strong>Learning time:</strong> 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 6h</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Elliptic partial differential equations</th>
<th><strong>Learning time:</strong> 32h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 4h</td>
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<tr>
<td></td>
<td>Self study: 24h</td>
</tr>
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<table>
<thead>
<tr>
<th>The finite element method</th>
<th><strong>Learning time:</strong> 32h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 24h</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Approximation of elliptic PDEs by the Galerkin finite elements method</th>
<th><strong>Learning time:</strong> 33h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 25h 30m</td>
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</table>

<table>
<thead>
<tr>
<th>Numerical approximation of the Navier-Stokes equations</th>
<th><strong>Learning time:</strong> 44h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 10h</td>
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<tr>
<td></td>
<td>Practical classes: 10h</td>
</tr>
<tr>
<td></td>
<td>Self study: 24h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Introduction to domain decomposition methods</th>
<th><strong>Learning time:</strong> 34h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 24h</td>
</tr>
</tbody>
</table>
Continuous assessment: during the course students will be required to carry out two projects. The projects must be done individually and they constitute the 50% of the final mark.

Final exam: at the end of the course a written exam will take place. The exam will focus on all the topics studied during the course and it constitutes the 50% of the final mark.

**Bibliography**

**Basic:**


**Complementary:**

34966 - VD - Differentiable Manifolds

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
Academic year: 2014
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
( Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

Teaching staff
Coordinator: FRANCESC XAVIER GRACIA SABATE
Others: FRANCESC XAVIER GRACIA SABATE - A

Prior skills
Basic courses on algebra, calculus, topology and differential equations, and calculus on manifolds.

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.
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:
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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 presented by students. Along the course the students will be given problems to solve as homework.

Learning objectives of the subject

The subject focuses on the fundamental topics used in differential geometry and applications in different areas.
By the end of the course, students should:
- Be able to understand all the ideas developed along the course.
- Be able to apply the studied concepts to other areas such as theoretical mechanics, control theory, mathematical physics or geometric dynamical systems.
- Be able to enter a research group on these kinds of topics and their applications.
- Be able to search the bibliography, and to understand the scientific literature on the subject.
- Be able to write and present an essay on mathematics.

<table>
<thead>
<tr>
<th>Study load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time</strong>: 187h 30m</td>
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<tr>
<td></td>
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<tr>
<td></td>
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</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic differential geometry</strong></td>
<td>37h 30m</td>
</tr>
<tr>
<td></td>
<td>Large group/Theory: 12h</td>
</tr>
<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
<tr>
<td><strong>Riemannian manifolds and symplectic manifolds</strong></td>
<td>37h 30m</td>
</tr>
<tr>
<td></td>
<td>Large group/Theory: 12h</td>
</tr>
<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
<tr>
<td><strong>Lie groups and Lie algebras</strong></td>
<td>50h</td>
</tr>
<tr>
<td></td>
<td>Large group/Theory: 16h</td>
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<tr>
<td></td>
<td>Self study : 34h</td>
</tr>
<tr>
<td><strong>Supplements on topology and analysis</strong></td>
<td>37h 30m</td>
</tr>
<tr>
<td></td>
<td>Large group/Theory: 12h</td>
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<tr>
<td></td>
<td>Self study : 25h 30m</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>25h</td>
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<tr>
<td></td>
<td>Large group/Theory: 8h</td>
</tr>
<tr>
<td></td>
<td>Self study : 17h</td>
</tr>
</tbody>
</table>

### Qualification system

Evaluation is based on students' participation and homework, and on the completion and presentation of an essay (a written work) on a topic on differential geometry. Eventually, there will be a final examination.
Bibliography

Basic:


Complementary:
