Guia Docent

12/13

Facultat de Matemàtiques
i Estadística

Master in Advanced Mathematics and Mathematical Engineering

Curs E. Galois
Program

As reflected in its name, this master 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. The master benefits both from the leading role of Spanish mathematical research at the European level and the technological environment of a technical university such as UPC–Barcelona Tech.

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 Algorithms; 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. The official teaching language of this master is English.

Specific requirements

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 these reasons, 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.

Career prospects

Some of the career prospects of master graduates are academic research (by pursuing a PhD in mathematics, sciences or engineering, for instance), mathematical modelling, finance, statistics, applied research (biomedical research centers, computer vision, etc.)
**Tutoring of the Students**

The initial tutoring is the responsibility of the Master’s Academic Coordinator (jfranch@ma4upc.edu) and is performed mainly in the period prior to enrollment, often online. In addition, there is a welcome session just before courses start.

Because the master duration is 60 ECTS, students should start early to worry about their final master thesis (TFM). In this sense, beyond the support of the Academic Coordinator, they have access to an intranet to determine which TFM's are available. There, they will find information about the range of topics, detailed objectives, content and teaching responsibility. Thus, at the end of the first term, students should already have chosen their TFM. From this point, the TFM advisor assumes tutoring.

**Additional information**

34950 - CALG - Commutative Algebra

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
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.

General:
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
# 34950 - CALG - Commutative Algebra

## Learning objectives of the subject

Basic course in Commutative Algebra.
An introduction to rings, ideal, primary decomposition, noetherian rings, integral extensions, completions and dimension theory.

## Content

### Rings and ideals

<table>
<thead>
<tr>
<th>Learning time: 12h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Self study: 9h 45m</td>
</tr>
</tbody>
</table>

**Description:**
It covers rings, ideals, radicals, extensions, and contractions.

### Modules

<table>
<thead>
<tr>
<th>Learning time: 12h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Self study: 9h 45m</td>
</tr>
</tbody>
</table>

**Description:**
General properties of modules. Tensor product.

### Rings and modules of fractions

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

**Description:**
Introduction to rings and modules of fractions

### Primary decompostion

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

**Description:**
Classical primary theory. First theorems.
### Integral dependence

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

**Description:**  
Definition of integral dependence. Theorems of going-up and going-down.

### Chain conditions

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

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

### Noetherian rings

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

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

### Artin rings

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

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

### Discrete valuation rings

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

**Description:**  
The next case. Noetherian rings of dimension one.
34950 - CALG - Commutative Algebra

**Completions**

**Learning time:** 18h  
**Description:** To deal with topologies, completions, filtrations and graded rings.

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

**Dimension theory**

**Learning time:** 18h  
**Description:** A brief introduction to Hilbert functions and dimension theory.

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

**Qualification system**

Continuous assessment, a final exam (if necessary)

**Bibliography**

**Basic:**


34951 - NCA - Non-Commutative Algebra

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 727 - MA III - Department of Applied Mathematics III
743 - MA IV - Department of Applied Mathematics IV
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5 Teaching languages: English

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

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

Requirements
The basic algebra courses from the degree in mathematics.

Degree competences to which the subject contributes

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

Generic:
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.
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.

### Content

#### Generalities about infinite groups

**Description:**
The free group: basic definitions. Presentations: generators and relations. Short exact sequences, direct and semidirect products. Free products, amalgams, HNN extensions. Thompson's group as an example.

**Learning time:** 47h
- Theory classes: 15h
- Self study: 32h

#### The classical Dehn problems in group theory

**Description:**
Description of the three classical algorithmic problems in group theory: word, conjugacy and isomorphism problems. Resolution of the word and conjugacy problems in simple cases: abelian, free, free-like constructions, residually finite, etc. Examples of algorithmically unsolvable problems: word, membership, isomorphism problems, $F_2 \times F_2$.

**Learning time:** 25h
- Theory classes: 8h
- Self study: 17h
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.

## 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.

### The free group

**Description:**
- Stallings foldings and the lattice of subgroups of the free group.
- Membership, conjugacy, finite index, intersection of subgroups.
- Hall's theorem and residual properties of free groups.

**Learning time:** 47h
- Theory classes: 15h
- Self study: 32h

### Cayley graphs

**Description:**
- Cayley graph and the word metric in a group.
- Dehn function, examples; characterization of the solvability of the word problem via Dehn functions.
- Growth of a group, examples. Gromov theorem.

**Learning time:** 31h
- Theory classes: 10h
- Self study: 21h

### Hyperbolic groups

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

**Learning time:** 37h 30m
- Theory classes: 12h
- Self study: 25h 30m
Bibliography

Basic:


Complementary:


34952 - AG - Algebraic Geometry

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
ECTS credits: 7.5  Teaching languages: English

Teaching staff
Coordinator: JAUME AMOROS TORRENT
Others: JAUME AMOROS TORRENT

Requirements
Basic abstract algebra, Topology and Differential Geometry
Commutative Algebra

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.

General:
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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.
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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 master classes where the different subjects are introduced and discussed with the students, and also some problem sessions.

Learning objectives of the subject
The main objective of the course is to introduce the student to the Algebraic Geometry of affine and projective varieties.
over a field. The course will be based on many examples, as in Harris book in the references, stressing the geometric interest of the subject, using the commutative algebra only as a resource. At the end, depending on the audience, there will be some lectures on schemes theory and their role in algebraic geometry.

### Study load

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

### Content

#### Chapter 1: Algebraic sets

**Description:**
Algebraic sets. Hilbert's basis and nullstellensatz theorems. Zariski topology.

**Learning time:** 18h
- Theory classes: 4h
- Self study: 14h

#### Chapter 2: Algebraic varieties

**Description:**

**Learning time:** 28h
- Theory classes: 9h
- Self study: 19h

#### Chapter 3: Projective varieties

**Description:**

**Learning time:** 28h
- Theory classes: 9h
- Self study: 19h
### Chapter 4: Finite maps

**Description:**

**Learning time:** 28h  
Theory classes: 9h  
Self study : 19h

### Chapter 5: Local theory

**Description:**

**Learning time:** 28h  
Theory classes: 9h  
Self study : 19h

### Chapter 6: Dimension theory

**Description:**
Dimension of affine varieties and of projective varieties. Dimension of the fibers of a morphism.

**Learning time:** 28h  
Theory classes: 9h  
Self study : 19h

### Chapter 7: Divisors, differentials and intersection theory

**Description:**
Divisors, intersectino theory of divisors. Bézout theorem. Differentials, the canonical divisor.

**Learning time:** 28h  
Theory classes: 9h  
Self study : 19h

### Qualification system

The qualification will be based on the exercises done as homework and the exposition of a subject developed by the student.
Bibliography

Basic:


34954 - CC - Codes and Cryptography

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

Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: M. PAZ MORILLO BOSCH
Others:
SIMEON MICHAEL BALL - A
JAVIER HERRANZ SOTOCA - A
M. 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.

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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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</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td></td>
<td>68.00%</td>
</tr>
</tbody>
</table>

### Content

#### Introduction to Coding theory

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

**Learning time:** 2h 24m
- Theory classes: 1h 36m
- Self study: 0h 48m

#### Information and Entropy

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

**Learning time:** 8h 55m
- Theory classes: 3h 37m
- Self study: 5h 18m

#### Source codes without memory

**Description:**

**Learning time:** 10h 55m
- Theory classes: 3h 37m
- Self study: 7h 18m
## 34954 - CC - Codes and Cryptography

### Channel coding

**Learning time:** 10h 55m  
- Theory classes: 3h 37m  
- Self study: 7h 18m

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

### Finite fields

**Learning time:** 8h 55m  
- Theory classes: 2h 37m  
- Self study: 6h 18m

**Description:**  
Irreducible polynomials over $\mathbb{Z}_p$. Construction of finite fields. The multiplicative group of a finite field.

### Block codes

**Learning time:** 21h 55m  
- Theory classes: 7h 37m  
- Self study: 14h 18m

**Description:**  

### Cyclic codes

**Learning time:** 21h 55m  
- Theory classes: 7h 37m  
- Self study: 14h 18m

**Description:**  

### Introduction to cryptography

**Learning time:** 4h 55m  
- Theory classes: 2h 37m  
- Self study: 2h 18m

**Description:**  
Symmetric key cryptography. Example AES.
### Public key cryptography

**Learning time:** 14h 55m  
Theory classes: 4h 37m  
Self study: 10h 18m


### Standard hard problems

**Learning time:** 14h 55m  
Theory classes: 4h 37m  
Self study: 10h 18m

**Description:** Factorization, discrete logarithm over finite fields and elliptic curves. Codes and lattices. Pairings over elliptic curves.

### Analysis of the security of cryptographic protocols

**Learning time:** 18h 55m  
Theory classes: 6h 37m  
Self study: 12h 18m

**Description:** Security models. Proofs by reduction. Heuristic security, random oracle model.

### Other cryptographic protocols of interest

**Learning time:** 14h 55m  
Theory classes: 4h 37m  
Self study: 10h 18m

**Description:** Identification protocols. Commitments. Zero-knowledge proofs.

### Distributed cryptography

**Learning time:** 18h 55m  
Theory classes: 6h 37m  
Self study: 12h 18m

**Description:** Secret sharing schemes. Multiparty computation. Application to distributed encryption and digital signatures protocols.
34954 - CC - Codes and Cryptography

<table>
<thead>
<tr>
<th>Directed project</th>
<th>Learning time: 14h 06m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study (distance learning): 14h 06m</td>
</tr>
</tbody>
</table>

**Description:**
CODING: Weight enumeration polynomial, perfect codes, error bursts, Reed-Muller codes (alternative version) and Kerdock codes. Symmetric codes over F3.

CRYPTOGRAPHY: Electronic voting, electronic commerce, management of private data, quantum cryptography.

**Qualification system**
Classroom problems: 2 points out of 10
Theory exam: 2.5 points out of 10
Supervised work (including oral presentation): 2 points out of 10
Final exam: 3.5 points out of 10

**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 - Faculty of Mathematics and Statistics
Teaching unit: 726 - MA II - Department of Applied Mathematics II
743 - MA IV - Department of Applied Mathematics IV

Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5

Teaching languages: English

Teaching staff
Coordinator: ORIOL SERRA ALBO
Others: SIMEON MICHAEL BALL - A
ANNA DE MIER VINUÉ - 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.

General:
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

There will be a lecture each week, followed by a problem session.
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: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
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Content

<table>
<thead>
<tr>
<th>Partially ordered sets</th>
<th>Learning time: 24h 40m</th>
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<tbody>
<tr>
<td>Description:</td>
<td></td>
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<tr>
<td>Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Extremal set theory</th>
<th>Learning time: 24h 40m</th>
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<tbody>
<tr>
<td>Description:</td>
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<tr>
<td>Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Linear algebra methods in combinatorics</th>
<th>Learning time: 18h 30m</th>
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</thead>
<tbody>
<tr>
<td>Description:</td>
<td></td>
</tr>
<tr>
<td>The polynomial method and applications. Fisher's theorem. Equiangular lines, sets with few differences</td>
<td></td>
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</tbody>
</table>
### Finite geometries

**Description:**

**Learning time:** 18h 30m
- **Theory classes:** 3h
- **Practical classes:** 3h
- **Self study:** 12h 30m

### Matroids

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

**Learning time:** 18h 30m
- **Theory classes:** 3h
- **Practical classes:** 3h
- **Self study:** 12h 30m

### Probabilistic methods in combinatorics

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

**Learning time:** 18h 30m
- **Theory classes:** 3h
- **Practical classes:** 3h
- **Self study:** 12h 30m

### Ramsey theory

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

**Learning time:** 31h 40m
- **Theory classes:** 5h
- **Practical classes:** 5h
- **Self study:** 21h 40m

### Enumerative combinatorics

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

**Learning time:** 32h 30m
- **Theory classes:** 5h
- **Practical classes:** 5h
- **Self study:** 22h 30m
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 - Faculty of Mathematics and Statistics
Teaching unit: 726 - MA II - Department of Applied Mathematics II
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: VERA SACRISTAN ADINOLFI
Others:
JULIAN PFEIFLE - A
VERA SACRISTAN ADINOLFI - 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.

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

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

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

Learning objectives of the subject

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

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

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

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>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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</tbody>
</table>

Content

**Preliminaries**

<table>
<thead>
<tr>
<th>Learning time: 12h 30m</th>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Self study : 8h 30m</td>
</tr>
</tbody>
</table>

**Description:**
Computational complexity. Data structures. Representation of geometric objects.
# 34956 - DG - Discrete and Algorithmic Geometry

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

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

| **Decompositions and arrangements** | **Learning time:** 31h  
| Theory classes: 7h  
| Practical classes: 3h  
| Self study: 21h  |

**Description:**  

| **Proximity Structures** | **Learning time:** 31h  
| Theory classes: 7h  
| Practical classes: 3h  
| Self study: 21h  |

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

| **Discrete geometry in arbitrary dimension** | **Learning time:** 37h  
| Theory classes: 8h  
| Practical classes: 4h  
| Self study: 25h  |

**Description:**  
### Nonlinear discrete geometry

<table>
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<tr>
<th>Description:</th>
<th>Learning time: 37h</th>
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| Positive semidefinite quadratic forms and sphere packings; Voronoi reductions; Delaunay subdivisions. Splines regarded as toric varieties; splines with linear precision in reconstructing functions. | Theory classes: 8h  
Practical classes: 4h  
Self study: 25h |

### Applications

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 11h</th>
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</table>
| GPS, GIS, structural rigidity and tensegrities; computational astrophysics, algorithmic chemistry; other applications. | Theory classes: 4h  
Self study: 7h |

### Software

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 9h</th>
</tr>
</thead>
</table>
| STL, CGAL, polymake, ANN, curved spaces, etc. | Laboratory classes: 2h  
Self study: 7h |

### Qualification system

In general, it will include an exam as well as class presentations. In the case of a small group, the exam may be replaced by personal work.

Nevertheless, the evaluation method may be adapted to the students' background, skills, and interests: programming problems or scientific research are considered as possible alternatives to the exam or the class presentations.
34956 - DG - Discrete and Algorithmic Geometry

Bibliography

Basic:


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

34957 - GT - Graph Theory

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
ECTS credits: 7,5  Teaching languages: English

Teaching staff

Coordinator: ORIOL SERRA ALBO
Others:
MIGUEL ANGEL FIO MORA - A
ANNA LLADO SANCHEZ - A
MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

Prior skills

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

Degree competences to which the subject contributes

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

General:
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.
34957 - GT - Graph Theory

Learning objectives of the subject

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

Study load

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

Content

Spectral techniques in Graph Theory

Description:

Symmetries in graphs

Minors and treewidth

Graphs on surfaces

Graph homomorphisms

Random graphs
The evaluation of the course is based on the weekly work on problems proposed in the presentation sessions. There will be a final comprehensive exam based on the problem sessions during the course.

Qualification system

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

Bibliography

Basic:


34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
ECTS credits: 7,5

Teaching languages: English

Teaching staff

Coordinator: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ
Others: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ - A

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.

General:
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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. The course will be split into two parts, one section will be more theoretical, covering techniques and basic models. The second will be more applied, building on the theory whilst focusing on a specific, practically important, application of PDEs to phase transition (e.g. ice melting, water evaporating, solidification of steel). This class of problems is of particular interest because it falls into the important field of Moving Boundary Problems, where the solution domain is unknown and must be solved for at the same time as the governing PDEs.

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.
* a more detailed knowledge of the mathematical models of phase transition and moving boundary problems.
* a more detailed knowledge of the mathematical techniques that are used in the solution of phase transitions problems.

### Content

#### 1 Modelling with PDEs

**Description:**
- Heat conduction and diffusion.
- Potentials in physics and technology.
- Transients in continuous media
- Populations dynamics.
- Equations of distribution of particles.
2 Phase Transitions

Learning time: 93h 45m
  - Theory classes: 30h
  - Self study: 63h 45m

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 an exam.

Bibliography

Basic:


Complementary:

34959 - CM - Computational Mechanics

**Coordinating unit:** 200 - FME - Faculty of Mathematics and Statistics

**Teaching unit:** 727 - MA III - Department of Applied Mathematics III

**Academic year:** 2012

**Degree:** MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).

(Teaching unit Optative)

**ECTS credits:** 7,5

**Teaching languages:** English

### Teaching staff

**Coordinator:** YONGXING SHEN

**Others:** YONGXING SHEN - 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.

**Generic:**

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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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; 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: 187h 30m</th>
<th>Theory classes: 60h (32.00%)</th>
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</thead>
<tbody>
<tr>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
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</table>

**Content**

**CONTINUUM MECHANICS**

**Learning time: 31h 15m**

- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m

**Description:**

**COMPUTATIONAL ELASTICITY**

**Learning time: 31h 15m**

- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m

**Description:**
# 34959 - CM - Computational Mechanics

## Computational Fluid Dynamics

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## Computational Plasticity

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<tr>
<td>Basic concepts and motivation. One-dimensional plasticity: elastic and plastic strains; elastoplastic constitutive equation; hardening. Multi-dimensional plasticity: stress and strain invariants; yield surface; plastic flow. Numerical time-integration of the constitutive equation: elastic prediction and plastic correction; iterative methods for the plastic correction. Applications.</td>
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## Computational Dynamics

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<th>Self study:</th>
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## Computational Methods for Wave Problems

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<th>Practical classes:</th>
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<table>
<thead>
<tr>
<th>Self study:</th>
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</thead>
<tbody>
<tr>
<td>21h 15m</td>
</tr>
</tbody>
</table>
Exam and assigned problems.

Bibliography

Basic:


Complementary:


34960 - MMB - Mathematical Models in Biology

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
726 - MA II - Department of Applied Mathematics II

Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: ANTONI GUILLAMON GRABOLOSA
Others: - MARTA CASANELLAS Rius

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.

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

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

### Study load

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

### Content

#### Models of Population Dynamics

**Learning time:** 56h 20m

- Theory classes: 9h
- Practical classes: 9h
- Self study: 38h 20m

**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
### Mathematical models in Genomics

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Brief introduction to genomics (genome, gen structure, genetic code...). Genome databases online.</td>
</tr>
<tr>
<td>4. Multiple sequence alignment: dynamical programming, tropical arithmetics and Pair-HMMs</td>
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<table>
<thead>
<tr>
<th>Learning time:</th>
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<tr>
<td>62h 30m</td>
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</table>

- Theory classes: 12h
- Practical classes: 8h
- Self study: 42h 30m

### Mathematical Models in Neurophysiology

<table>
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<tr>
<th>Learning time:</th>
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<tbody>
<tr>
<td>56h 20m</td>
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- Theory classes: 11h
- Practical classes: 7h
- Self study: 38h 20m

### Biological networks

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<th>Learning time:</th>
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<tr>
<td>12h 20m</td>
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- Theory classes: 3h
- Practical classes: 1h
- Self study: 8h 20m

<table>
<thead>
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<th>Description:</th>
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<tbody>
<tr>
<td>2. Networks of neurons.</td>
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</table>

### Qualification system

The course has three parts and each of these parts will give a part of the qualification, based on practical problems to be delivered. Besides, students will be asked to write a report on a specialized subject (from a list of suggested topics) and deliver it 2 days before presenting it in front of the students and teachers. The contents and the clarity of explanations and exposition.

The final qualification will be given by the formula $0.6 \times NP + 0.4 \times NT$ where:

- $NP = NP1 + NP2 + NP3$ practice qualification: this is the qualification of 3 practical qualifications and the participation at class.

- $NT =$ report qualification.
Bibliography

Basic:


Complementary:


34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

**Coordinating unit:** 200 - FME - Faculty of Mathematics and Statistics  
**Teaching unit:** 725 - MA I - Department of Applied Mathematics I  
**Academic year:** 2012  
**Degree:** MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).  
(Teaching unit Optative)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** M. TERESA MARTINEZ-SEARA ALONSO

**Others:**
AMADEU DELSHAMS I VALDES - A  
M. TERESA MARTINEZ-SEARA ALONSO - A

### Opening hours

**Timetable:** A convenir

### 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.

#### Generical:

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 perturvaties 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>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
</tr>
</tbody>
</table>

Content

- **Invariant objects in Dynamical Systems**

  **Description:**

  **Learning time:** 20h
  Theory classes: 5h
  Practical classes: 5h
  Other activities: 10h

- **Perturbation theory in Dynamical Systems**

  **Description:**
  Clasic perturbation theory. Perturbed homoclinic orbits in the plane. Melnikov method.

  **Learning time:** 20h
  Theory classes: 5h
  Practical classes: 5h
  Other activities: 10h
### Discrete Dynamical Systems

**Description:**

**Learning time:** 20h  
Theory classes: 5h  
Practical classes: 5h  
Other activities: 10h

### Homoclinic points and chaotic Dynamics

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

**Learning time:** 20h  
Theory classes: 5h  
Practical classes: 5h  
Other activities: 10h

### Normal forms

**Description:**

**Learning time:** 20h  
Theory classes: 5h  
Practical classes: 5h  
Other activities: 10h

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

**Description:**

**Learning time:** 20h  
Theory classes: 5h  
Practical classes: 5h  
Other activities: 10h
### Qualification system

The students have to do some problems and a research work. On the other hand they will attend the "Jornades d'iniciació als Sistemes dinàmics i les EDP" and produce a document about them.

### Regulations for carrying out activities

There are no exams.

### Bibliography
34962 - HS - Hamiltonian Systems

**Coordinating unit:** 200 - FME - Faculty of Mathematics and Statistics  
**Teaching unit:** 725 - MA I - Department of Applied Mathematics I  
**Academic year:** 2012  
**Degree:** MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)  
**ECTS credits:** 7,5  
**Teaching languages:** English

**Teaching staff**

**Coordinator:** AMADEU DELSHAMS I VALDES  
**Others:** AMADEU DELSHAMS I VALDES - 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.

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

**Teaching methodology**

Standard exposition in front of the blackboard, resolution of exercises, completion of a project and/or attendance to the winter school RTNS.  
34962 - HS - Hamiltonian Systems

**Learning objectives of the subject**

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

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>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>

**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

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

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

### 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

### Discrete dynamical systems

**Description:**

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

### Recent Trends in Nonlinear Science

**Description:**
Smooth Ergodic Theory: Lyapunov exponents, Oseledets' Theorem, nonuniform hyperbolicity.
Delay equations with applications to engineering: delay equations, stability, bifurcations.
Multi-frequency Oscillations in Dynamical Systems.

**Learning time:** 57h 30m  
Theory classes: 20h  
Self study: 37h 30m

### Planning of activities

#### RECENT TRENDS IN NONLINEAR SCIENCE

**Description:**

**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 RTNS and produce a document about them.

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 - Faculty of Mathematics and Statistics

**Teaching unit:** 725 - MA I - Department of Applied Mathematics I

**Academic year:** 2012

**Degree:** MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)

**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** XAVIER CABRE VILAGUT

**Others:**

BLANCA AYUSO DE DIOS - A  
XAVIER CABRE VILAGUT - 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.

**Generic:**

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

## Content

### Classical methods for the Poisson and heat equations

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

#### Learning time: 47h
- Theory classes: 15h
- Self study: 32h

### Sobolev spaces and variational methods

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

#### Learning time: 47h
- Theory classes: 15h
- Self study: 32h

### Evolution equations

#### Description:

#### Learning time: 46h 45m
- Theory classes: 15h
- Self study: 31h 45m
Introduction to nonlinear PDEs

Description:

Learning time: 46h 45m
Theory classes: 15h
Self study: 31h 45m

Qualification system

The evaluation of the course is based:
- on the weekly resolution of problems proposed in class;
- on a presentation (written and in class) of a further developed topic on the subject;
- eventually there will be a final comprehensive exam.

The active participation during the course will be a requirement for the evaluation of the final exam.

Bibliography

Basic:

Complementary:
34964 - NMDS - Numerical Methods for Dynamical Systems

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: MERCEDES OLLE TORNER
Others: 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.

General:
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.
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 analyze 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>
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</tr>
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<tbody>
<tr>
<td></td>
<td>32.00%</td>
<td>68.00%</td>
</tr>
</tbody>
</table>

Content

**Numerical (preliminary) tools for practical purposes: integrators for ODE and graphical interfaces. Examples.**

Learning time: 4h
- Theory classes: 2h
- Practical classes: 2h

**Dynamical systems: introduction, definitions. Continuous and discrete dynamical systems. Orbit generation. Numerical computation of Poincare maps. Examples.**

Learning time: 6h
- Theory classes: 3h
- Practical classes: 3h

**Computation and stability of fixed points. Vector fields and maps. Implementation and examples.**

Learning time: 10h
- Theory classes: 5h
- Practical classes: 5h

**Computation and stability of periodic orbits. Implementation, continuation of families, bifurcations. Multiple shooting.**

Learning time: 10h
- Theory classes: 5h
- Practical classes: 5h
34964 - NMDS - Numerical Methods for Dynamical Systems

### Computation of tori: representation, computation and continuation. Implementation and examples.

<table>
<thead>
<tr>
<th>Learning time: 15h</th>
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<tbody>
<tr>
<td>Theory classes: 7h 30m</td>
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<tr>
<td>Practical classes: 7h 30m</td>
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</table>

### Analysis of bifurcations. Some examples.

<table>
<thead>
<tr>
<th>Learning time: 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 7h 30m</td>
</tr>
<tr>
<td>Practical classes: 7h 30m</td>
</tr>
</tbody>
</table>

#### 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 - Faculty of Mathematics and Statistics
Teaching unit: 727 - MA III - Department of Applied Mathematics III
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
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.

General:
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.

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

| Total learning time: 187h 30m | Theory classes: 60h 32.00% | Self study: 127h 30m 68.00% |

### Content

**Introduction to partial differential equations and basics of functional analysis**

<table>
<thead>
<tr>
<th>Learning time: 12h</th>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
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<tr>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Self study: 6h</td>
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**Elliptic partial differential equations**

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

<table>
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<th>Learning time: 32h</th>
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<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Practical classes: 4h</td>
</tr>
<tr>
<td>Self study: 24h</td>
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</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 30% 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 70% of the final mark.

### Approximation of elliptic PDEs by the Galerkin finite elements method

- **Learning time:** 33h 30m
  - Theory classes: 4h
  - Practical classes: 4h
  - Self study: 25h 30m

### Numerical approximation of the Navier-Stokes equations

- **Learning time:** 44h
  - Theory classes: 10h
  - Practical classes: 10h
  - Self study: 24h

### Introduction to domain decomposition methods

- **Learning time:** 34h
  - Theory classes: 6h
  - Practical classes: 4h
  - Self study: 24h
Bibliography

Basic:


Complementary:


34966 - VD - Differentiable Manifolds

Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
Academic year: 2012
Degree: MASTER IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: FRANCESC XAVIER GRACIA SABATE
Others: FRANCESC XAVIER GRACIA SABATE - A
MIGUEL CARLOS MUÑOZ LECANDA - 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.
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.

Generic:
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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7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

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

### Study load

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

<table>
<thead>
<tr>
<th>Basic differential geometry and riemannian geometry</th>
<th>Learning time: 47h</th>
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<table>
<thead>
<tr>
<th>Basic algebraic topology and topological algebra</th>
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<table>
<thead>
<tr>
<th>Lie groups and Lie algebras</th>
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<td></td>
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<table>
<thead>
<tr>
<th>Some applications of Lie groups</th>
<th>Learning time: 31h</th>
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<tr>
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</table>
34966 - VD - Differentiable Manifolds

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:


