Master of Science in Advanced Mathematics and Mathematical Engineering

1913-1996

Guia Docent
10/11

Facultat de Matemàtiques i Estadística

Curs Paul Erdős
Master of Science in Advanced Mathematics and Mathematical Engineering

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.)
Additional information


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.
Coordinating unit: 200 - FME - Faculty of Mathematics and Statistics
Teaching unit: 725 - MA I - Department of Applied Mathematics I
Academic year: 2010
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: XAVIER CABRE VILAGUT

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.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
### 34963 - ACPDE - Advanced Course in Partial Differential Equations

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

#### Learning objectives of the subject
Understand the regularity of a function through its Sobolev norms and their relations. Understand the role of 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>Self study: 127h 30m</th>
<th>68.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 60h</td>
<td>32.00%</td>
</tr>
</tbody>
</table>

#### Content

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

<table>
<thead>
<tr>
<th>Variational formulation of elliptic problems</th>
<th>Learning time: 47h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td>Weak or variational formulation of boundary problems for linear EDPS. Finite element method. Regularity of the solutions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self study: 32h</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Variational formulation of evolution problems</th>
<th>Learning time: 31h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td></td>
<td>Self study: 21h</td>
</tr>
</tbody>
</table>
Introduction to nonlinear EDPS

Description:

Learning time: 62h 30m
Theory classes: 20h
Self study: 42h 30m

Qualification system

Resolution of topics and exercises that are left incomplete in class. Presentation in class of a further developed topic of the subject.

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: 2010
ECTS credits: 7,5  Teaching languages: English

Teaching staff

Coordinator: PEDRO PASCUAL GAINZA

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:
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 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

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<tbody>
<tr>
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</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: 2010
Degree: MASTER IN ADVANCED MATHEMATICAL AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Teaching unit Optative)
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: M. PAZ MORILLO BOSCH
Others: Jorge Luis Villar, Javier Herranz, Simeon Ball

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.
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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.
34954 - CC - Codes and Cryptography

Teaching methodology

The course is divided in two parts: codes and cryptography. Each part consists of 26 h of ordinary classes and 13 of supervised works. In these works some specialized topics will be addressed in deep.

Learning objectives of the subject

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 importants 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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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>127h 30m</td>
</tr>
<tr>
<td>Theory classes:</td>
<td>60h</td>
</tr>
<tr>
<td></td>
<td>68.00%</td>
</tr>
<tr>
<td></td>
<td>32.00%</td>
</tr>
</tbody>
</table>

Content

**Introduction to Coding theory**

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

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

**Information and Entropy**

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

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

**Source codes without memory**

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

**Description:**
### Channel coding

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

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

### Finite fields

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

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

### Block codes

**Description:**

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

### Cyclic codes

**Description:**
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.

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

### Introduction to cryptography

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

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


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

### Standard hard problems

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

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

### Analysis of the security of cryptographic protocols

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

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

### Other cryptographic protocols of interest

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

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

### Distributed cryptography

**Description:** Secret sharing schemes. Multiparty computation. Application to distributed encryption and digital signatures protocols.

**Learning time:** 18h 55m  
Theory classes: 6h 37m  
Self study: 12h 18m
34954 - CC - Codes and Cryptography

<table>
<thead>
<tr>
<th>Directed project</th>
<th>Learning time:</th>
<th>Learning time:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14h 06m</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: 2010
ECTS credits: 7.5
Teaching languages: English

Teaching staff

Coordinator: MARCOS NOY SERRANO

Others: BALL, SIMEON
DE MIER VINÚE, ANNA
ORIOL SERRA ALBO

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:
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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

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

### Content

#### Partially ordered sets

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

#### Extremal set theory

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

#### Linear algebra methods in combinatorics

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

### Study load

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

**Learning time:**
- **Total learning time:** 187h 30m
- **Theory classes:** 12h 40m
- **Practical classes:** 4h
- **Self study:** 16h 40m
# 34955 - COMB - Combinatorics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finite geometries</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>q-anologs of extremal problems. Segre's theorem. Blocking sets, ovals and hyperovals.</td>
</tr>
<tr>
<td><strong>Matroids</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Axioms. Transversal matroids. Greedy algorithms. The Tutte polynomial</td>
</tr>
<tr>
<td><strong>Probabilistic methods in combinatorics</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Permanents, transversals, hypergraph coloring. Monotone properties and threshold functions</td>
</tr>
<tr>
<td><strong>Ramsey theory</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Theorems of Ramsey and Hales-Jewett. Theorems of Schur, Van der Waerden and Rado.</td>
</tr>
<tr>
<td><strong>Enumerative combinatorics</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Symbolic and analytic methods. Symmetries and Pólya theory.</td>
</tr>
</tbody>
</table>
Grading will be based on the solution of exercises. Eventually there will be a final examination.

Bibliography

Basic:

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:** 2010

**ECTS credits:** 7.5

**Teaching languages:** English

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### Teaching staff

**Coordinator:** FRANCESC PLANAS VILANOVA

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### Prior skills

Linear algebra, calculus, topology, analysis.

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### Requirements

The two first years of a degree in mathematics.

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### 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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### Teaching methodology

Teaching Classes, resolution of problems

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### 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.

### Study load

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</tr>
</tbody>
</table>

### Content

#### Rings and ideals

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

**Learning time:** 12h 45m
- Theory classes: 3h
- Self study: 9h 45m

#### Modules

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

**Learning time:** 12h 45m
- Theory classes: 3h
- Self study: 9h 45m

#### Rings and modules of fractions

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

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

#### Primary decomposition

**Description:**
Classical primary theory. First theorems.

**Learning time:** 18h
- Theory classes: 6h
- Self study: 12h
### Integral dependence

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

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

### Chain conditions

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

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

### Noetherian rings

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

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

### Artin rings

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

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

### Discrete valuation rings

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

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

Description:
To deal with topologies, completions, filtrations and graded rings.

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

Dimension theory

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

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

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

Bibliography

Basic:


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: 2010
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: ANTONIO RODRIGUEZ FERRAN
Others: JOSE JAVIER MUÑOZ ROMERO

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.
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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.
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; lists of problems. Students will work on these problems individually or in pairs.
The main objective is to provide a general perspective of the broad field of computational mechanics, covering both the modelling and the computational aspects. A broad range of problems is addressed: solids, fluids and fluid-solid interaction; linear and nonlinear models; static and dynamic problems. By the end of the course, the students should:
- Be able to choose the appropriate type of model for a specific simulation
- Be familiar with the mathematical objects (mainly tensors) used in computational mechanics
- Be aware of the different level of complexity of various problems (e.g. linear vs. nonlinear, static vs. dynamic).

**Learning objectives of the subject**

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Self study: 127h 30m</th>
<th>68.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 60h</td>
<td>Practical classes: 2h</td>
<td>32.00%</td>
</tr>
</tbody>
</table>

**Content**

**CONTINUUM MECHANICS**

- **Description:**

**COMPUTATIONAL ELASTICITY**

- **Description:**
### Computational Fluid Dynamics

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

**Description:**  

### Computational Plasticity

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

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

### Computational Dynamics

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

### Computational Methods for Wave Problems

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

**Description:**  
Basic concepts and motivation.  
Exam and assigned problems.

Bibliography

Basic:


Complementary:


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: 2010
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: VERA SACRISTAN ADINOLFI
Others: FERNANDO ALFREDO HURTADO DIAZ - JULIAN PFEIFLE

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.
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

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

Content

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

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Convexity**                              | 19h           | Theory classes: 4h  
Practical classes: 2h  
Self study: 13h                                                                 |
| **Description:**                           |               | Convex hull computation. Linear programming in low dimensions.                                |
| **Decompositions and arrangements**        | 31h           | Theory classes: 7h  
Practical classes: 3h  
Self study: 21h                                                                 |
| **Description:**                           |               | Subdivisions and triangulations of point sets and polygons. Visibility and motion planning.  
Complexity. Levels and k-sets.               |
| **Proximity Structures**                  | 31h           | Theory classes: 7h  
Practical classes: 3h  
Self study: 21h                                                                 |
| **Description:**                           |               | Proximity problems. Voronoi diagram, Delaunay triangulation. Shape reconstruction.               |
| **Discrete geometry in arbitrary dimension** | 37h           | Theory classes: 8h  
Practical classes: 4h  
Self study: 25h                                                                 |
### 34956 - DG - Discrete and Algorithmic Geometry

#### Nonlinear discrete geometry

**Description:**
Positive semidefinite quadratic forms and sphere packings; Voronoi reductions; Delaunay subdivisions. Splines regarded as toric varieties; splines with linear precision in reconstructing functions.

**Learning time:** 37h  
- Theory classes: 8h  
- Practical classes: 4h  
- Self study: 25h

#### Applications

**Description:**
GPS, GIS, structural rigidity and tensegrities; computational astrophysics, algorithmic chemistry; other applications.

**Learning time:** 11h  
- Theory classes: 4h  
- Self study: 7h

#### Software

**Description:**
STL, CGAL, polymake, ANN, curved spaces, etc.

**Learning time:** 9h  
- 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.
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

Teaching staff

Coordinator: ORIOL SERRA ALBO
Others: Miquel Angel Fiol, Anna Lladó, Marc Noy

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.
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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.

Prior skills

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

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

### Study load

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

### Content

#### Spectral techniques in Graph Theory

**Description:**

#### Symmetries in graphs

#### Minors and treewidth

#### Graphs on surfaces

#### Graph homomorphisms

#### Random graphs
### Extremal Graph Theory

<table>
<thead>
<tr>
<th>Learning time: 75h</th>
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<tr>
<td>Theory classes: 24h 10m</td>
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<tr>
<td>Practical classes: 24h 10m</td>
</tr>
<tr>
<td>Assessment sessions: 3h</td>
</tr>
<tr>
<td>Self study (distance learning): 23h 40m</td>
</tr>
</tbody>
</table>

### 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:**


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: 2010
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: AMADEU DELSHAMS I VALDES
Others: PERE GUTIERREZ SERRES

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.
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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.
34962 - HS - Hamiltonian Systems

Teaching methodology

Standard exposition in front of the blackboard, resolution of exercises, completion of a project and/or attendance to RTNS2011
http://www.dance-net.org/rtns2011/

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

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<tr>
<th>Total learning time: 187h 30m</th>
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<tr>
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<td>Theory classes: 4h</td>
<td></td>
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<tr>
<td></td>
<td>Practical classes: 4h</td>
<td></td>
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<tr>
<td></td>
<td>Self study : 18h</td>
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</table>

Study load

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<tr>
<td></td>
<td>Practical classes: 4h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self study : 18h</td>
<td></td>
</tr>
</tbody>
</table>

Content

Hamiltonian formalism

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

Learning time: 26h

- Theory classes: 4h
- Practical classes: 4h
- Self study : 18h

Hamiltonian and Lagrangian systems

Description:

Learning time: 13h

- Theory classes: 2h
- Practical classes: 2h
- Self study : 9h
### 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

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

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

### Homoclinic points and chaotic dynamics

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

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

**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.

---

### Bibliography

#### Basic:


#### Others resources:

- **Hyperlink**
  - [Grup de sistemes dinàmics](https://recerca.upc.edu/sd)
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: 2010
Degree: MASTER IN ADVANCED MATHEMATICAL AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)
ECTS credits: 7.5
Teaching languages: English

Teaching staff
Coordinator: JOAN DE SOLÀ-MORALES RUBIÓ
Others: TIM MYERS

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.
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

**Teaching methodology**

The course is divided into two parts that will run in parallel. One part is a general overview of problems that can be modelled with PDEs and the other part focuses on a particular topic with industrial applications, namely Phase Transitions.

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

**Learning objectives of the subject**

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

**Study load**

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

**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.

**Learning time:** 93h 45m
- Theory classes: 30h
- Self study: 63h 45m
2 Phase Transitions

Description:
- Introduction to phase change problems and exact solutions.
- Mathematical techniques for phase change and moving boundary problems
- Integral methods.
- Approximate solutions methods.
- Practical applications.

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:
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: 2010
ECTS credits: 7,5
Teaching languages: English

Teaching staff
Coordinator: JOAQUIM PUIG SADURNI
Others: MARTA CASANELLAS RIUS
ANTONI GUILLAMON GRABOLOSA

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.

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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.
34960 - MMB - Mathematical Models in Biology

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

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

Teaching methodology

The course will consist of lectures, problem sessions and practical computer sessions. Lectures will consist of expositions about the contents of this subject following a biological problem.

Both practical sessions and problem sessions will be in a PC room and will help the student to develop part of the subject with extensions to the lectures, practical problems with real or simulated data and algorithms to perform these operations. The SAGE computing environment will be used, with interfaces to Python, R and C if necessary.

Learning objectives of the subject

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

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

Study load

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

**Learning time:** 62h 30m
- Theory classes: 12h
- Practical classes: 8h
- Self study: 42h 30m

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

### Mathematical Models in Physiology

**Learning time:** 56h 20m
- Theory classes: 11h
- Practical classes: 7h
- Self study: 38h 20m

**Description:**
1. Enzymatic reactions and Michaelis-Menten theory.
3. Pancreatic Beta cells and bursting models.
4. Models in systems physiology: hormone physiology, respiration, cardiac activity.
# 34960 - MMB - Mathematical Models in Biology

## Biological networks

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
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<tbody>
<tr>
<td>3. Firing rate models and mean field techniques in cell networks.</td>
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<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Practical classes: 1h</td>
</tr>
<tr>
<td>Self study : 8h 20m</td>
</tr>
</tbody>
</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.
- $NT$=report qualification.
Bibliography

Basic:


Complementary:


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: 2010
ECTS credits: 7,5 Teaching languages: English

Teaching staff
Coordinator: JOSE BURILLO PUIG
Others: Enric Ventura Capell

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.

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.
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.

Learning objectives of the subject

Study of the theory of nonabelian infinite groups. The concept of presentation as a basic tool to understand infinite groups. The free group and its subgroups. Study of the classical decision problems in group theory. Geometric methods for studying groups.

Study load

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

Content

Generalities sobre grups.

**Description:**
- Presentations: generators and relations
- Short exact sequences, direct and semidirect products.
- Free products, malagams, HNN extensions
- The braid group as an example.

Learning time: 8h

The free group

**Description:**
- The nonabelian free group, definition.
- Uniqueness of reduced words.
- Stallings foldings and subgroups of the free group
- Howson's theorem and Hanna Neumann conjecture.

Learning time: 12h

Separability conditions

**Description:**
- Residually finite groups
- Subgroup separability
- Hopfian groups

Learning time: 4h
The student will have to develop a subject, first in term paper form, of about 15-20 pages, and also as a one-hour lecture. The subject can be assigned, or it can be picked by the student, being able to choose something related to his future work.

### 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-hour lecture. The subject can be assigned, or it can be picked by the student, being able to choose something related to his future work.
Bibliography

**Basic:**


**Complementary:**


34953 - NT - Number Theory

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: 2010
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: VICTOR ROTGER CERDÀ

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.

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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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
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.
34953 - NT - Number Theory

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

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

Content

Algebraic Number Theory

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

Elliptic Curves

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

Qualification system

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

Regulations for carrying out activities

Solved exercises and works must be delivered on the last day of the course.
Bibliography

Basic:

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:** 2010

**ECTS credits:** 7,5

**Teaching languages:** English

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**Teaching staff**

**Coordinator:** MERCEDES OLLE TORNER

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**Prior skills**

Good knowledge of a programming language.

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**Requirements**

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

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**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.

**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.

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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.

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**Teaching methodology**

Theoretical sessions (presence of the students is necessary) and weekly practical tutorized assignments.
34964 - NMDS - Numerical Methods for Dynamical Systems

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>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 60h</td>
<td>32.00%</td>
</tr>
</tbody>
</table>

Content

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

<table>
<thead>
<tr>
<th>Learning time: 4h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 2h</td>
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<tr>
<td>Practical classes: 2h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning time: 6h</th>
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<tbody>
<tr>
<td>Theory classes: 3h</td>
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<tr>
<td>Practical classes: 3h</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning time: 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
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<tr>
<td>Practical classes: 5h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning time: 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Practical classes: 5h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Learning time: 15h</th>
</tr>
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<tbody>
<tr>
<td>Theory classes: 7h 30m</td>
</tr>
<tr>
<td>Practical classes: 7h 30m</td>
</tr>
</tbody>
</table>
34964 - NMDS - Numerical Methods for Dynamical Systems

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

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

<table>
<thead>
<tr>
<th>Coordinating unit:</th>
<th>200 - FME - Faculty of Mathematics and Statistics</th>
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</thead>
<tbody>
<tr>
<td>Teaching unit:</td>
<td>727 - MA III - Department of Applied Mathematics III</td>
</tr>
<tr>
<td>Academic year:</td>
<td>2010</td>
</tr>
<tr>
<td>Degree:</td>
<td>MASTER IN ADVANCED MATHEMATICAL AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optative)</td>
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<td>ECTS credits:</td>
<td>7,5</td>
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<tr>
<td>Teaching languages:</td>
<td>English</td>
</tr>
</tbody>
</table>

Teaching staff

Coordinator: ZLOTNIK, SERGIO

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:
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Teaching methodology

Lectures, practical work at computer room, exercises and home works. Some exercises and home works will involve use of finite element or finite difference basic programs and some coding.
Learning objectives of the subject

This module presents the fundamentals of classical numerical techniques for linear partial differential equations (PDEs), with application to a wide variety of problems in science, engineering, and other fields. Learning outcomes are:

* A knowledge and understanding of
  - the fundamentals of classical numerical techniques for linear PDEs,
  - the derivation of weak forms and their solution,
  - why finite elements approximate and converge to the solution of a PDE,
  - the basic structure of a finite element code,
  - different methods for prescribing boundary conditions,
  - how to solve transient problems,
  - stability properties for explicit and implicit time integrators
  - basics on stabilization techniques for convection dominated problems

* Ability to
  - identify the key issues when solving a boundary value problem,
  - employ appropriate order polynomials together with appropriate integration rules,
  - solve simple boundary value problems by hand,
  - analyze the convergence and stability of a numerical scheme,
  - use a simple FE or FD computer code to set up and produce results for computational simulation,
  - formulate and implement simple key aspects of a FE code,
  - check the reliability and accuracy of a computed solution.

Content

Overview of partial differential equations

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical and physical classification of PDEs. Problems in engineering and applied sciences modeled by PDEs.</td>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 4h</td>
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Study load

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

| 6h | 32.00% |
# 34965 - NMPDE - Numerical Methods for Partial Differential Equations

<table>
<thead>
<tr>
<th>Finite element method for elliptic equations</th>
<th>Learning time: 35h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Fundamentals of the Finite Element Method (FEM): weighted residuals, finite element discretization, reference element and isoparametric transformation, numerical integration. Structure of a basic FEM code. Overview of linear solvers</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis of the FEM: existence and uniqueness of solution and convergence</th>
<th>Learning time: 15h</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Implementation of boundary conditions</th>
<th>Learning time: 25h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Techniques for the implementation of Dirichlet boundary conditions: system transformation, Lagrange multipliers, Nitsche’s method, etc.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parabolic equation</th>
<th>Learning time: 50h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Space and time integration of the parabolic equation. Classical methods for time integration: Euler, backward Euler and Crank-Nicolson. Stability analysis for 1D problems: amplification matrix analysis and Von Neumann analysis.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Theory classes: 6h</th>
<th>Practical classes: 10h</th>
<th>Self study: 34h 30m</th>
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<tbody>
<tr>
<td>Theory classes: 5h</td>
<td>Practical classes: 6h</td>
<td>Self study: 24h</td>
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<tr>
<td>Theory classes: 3h</td>
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<tr>
<td>Theory classes: 4h</td>
<td>Practical classes: 4h</td>
<td>Self study: 17h</td>
</tr>
<tr>
<td>Theory classes: 6h</td>
<td>Practical classes: 10h</td>
<td>Self study: 34h 30m</td>
</tr>
</tbody>
</table>
Introduction to stabilization techniques for convection dominated problems

Learning time: 28h
- Theory classes: 5h
- Practical classes: 4h
- Self study: 19h

Description:
Analysis of the 1D convection-diffusion equation and Peclèt number.
Classical stabilization techniques

Introduction to accuracy assessment and adaptivity

Learning time: 28h
- Theory classes: 5h
- Practical classes: 4h
- Self study: 19h

Description:
Introduction to error estimation and error bounds. Remeshing and adaptivity strategies

Qualification system
Continuous assessment assignments and end of semester open-book examination.

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: 2010
ECTS credits: 7,5
Teaching languages: English

Teaching staff

Coordinator: M. TERESA MARTINEZ-SEARA ALONSO
Others: Amadeu Delshams Valdés

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.

Generic:
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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

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 perturbative techniques to study a dynamical system globally.

Learning objectives of the subject

Study load

<table>
<thead>
<tr>
<th></th>
<th>Total learning time</th>
<th>Self study:</th>
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</tr>
<tr>
<td></td>
<td>60h</td>
<td></td>
<td>32.00%</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:**
  
  Classic perturbation theory. Perturbed homoclinic orbits in the plane. Melnikov method.
### 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