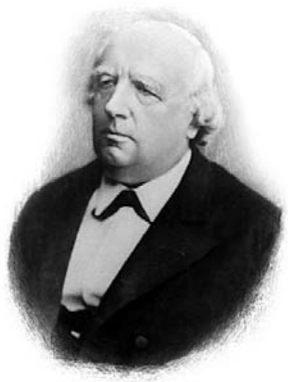
# Guia Docent

# 14/15

## Facultat de Matemàtiques i Estadística

Curs Weierstrass



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## Master in Advanced Mathematics and Mathematical Engineering

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat de Matemàtiques i Estadística

## Sumari:

## General information MAMME

### Introduction

### Competencies

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### Curriculum

### Admission

# MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (MAMME)

2014-2015 ACADEMIC YEAR

## INTRODUCTION

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

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

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

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

Consult the list of candidates admitted

| | |
|---|---|
| **Pre-enrolment** | Open |
| **Starting** | September |
| **Duration** | One academic year |
| **ECTS credits** | 60 |
| **Delivery** | Face-to-face |
| **Languages of instruction** | English |
| **Organised by** | School of Mathematics and Statistics (FME) |
| **Prospective students** | Anyone with good abstract reasoning, interest in problem solving, strong work habits and a liking for mathematics. |
| **Location** | Facultat de Matemàtiques i Estadística (FME)<br>Campus Diagonal Sud. Edifici U. C. Pau Gargallo, 5<br>08028 Barcelona |
| **Prices** | €51.46 per ECTS credit. For non-residents who are not EU nationals, the cost is 1.5 times the ordinary cost of one credit. |
| **Website** | http://mamme.masters.upc.edu |
| **E-mails** | cap.estudis.matematiques.fme@upc.edu |

# Curriculum

## CURRICULUM

| | Subjects | ECTS credits | Type |
|---|---|---|---|
| **FIRST SEMESTER** | Advanced Course in Partial Differential Equations | 7.5 | Optional |
| | Algebraic Geometry | 7.5 | Optional |
| | Codes and Cryptography | 7.5 | Optional |
| | Combinatorics | 7.5 | Optional |
| | Commutative Algebra | 7.5 | Optional |
| | Computational Mechanics | 7.5 | Optional |
| | Differentiable Manifolds | 7.5 | Optional |
| | Discrete and Algorithmic Geometry | 7.5 | Optional |
| | Graph Theory | 7.5 | Optional |
| | Hamiltonian Systems | 7.5 | Optional |
| | Mathematical Modelling with Partial Differential Equations | 7.5 | Optional |
| | Mathematical Models in Biology | 7.5 | Optional |
| | Non-Commutative Algebra | 7.5 | Optional |
| | Number Theory | 7.5 | Optional |
| | Numerical Methods for Dynamical Systems | 7.5 | Optional |
| | Numerical Methods for Partial Differential Equations | 7.5 | Optional |
| | Quantitative and Qualitative Methods in Dynamical Systems | 7.5 | Optional |

## COMPETENCIES

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

**Generic competencies**

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

**Specific skills**

1. (Research). Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. (Modelling). Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. (Calculus). Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. (Critical assessment). Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
5. (Teaching). Teach mathematics at university level.

## PROFESSIONAL OPPORTUNITIES

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

## ADMISSION

| | |
|---|---|
| **General requirements** | Academic regulations |
| **Specific requirements** | Recommended background<br><br>This master is addressed to students with good abstract reasoning, interest in problem solving, strong work habits and a liking for mathematics.<br><br>A scientific background is required, with basic mathematical foundations. For this reason, a bachelor in mathematics, statistics, physics, engineering, economics or science is recommended. This list is non-exclusive, and all applications will be reviewed on an individual basis. |
| **Admission criteria** | The following elements will be taken into consideration during the evaluation process: academic record, CV, statement of purpose and, if deemed necessary, personal interview and recommendation letters. |
| **Entry places** | 30 |
| **Pre-enrolment** | Pre-enrolment period open.<br>How to pre-enrol |
| **Candidates admitted** | Consult the list of candidates admitted |
| **Enrolment** | How to enrol |

# Program

## Structure

### 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

### 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:

| Area | Field |
|---|---|
| **A**<br>Algebra, Geometry, Discrete Mathematics and Algorithmics<br>(60 ECTS) | Algebra and Geometry (30 ECTS) |
| | Discrete Mathematics and Algorithmics (30 ECTS) |
| **B**<br>Modelling, Differential Equations and Scientific Computing<br>(60 ECTS) | Modelling in Engineering and Biomedical Sciences (22.5 ECTS) |
| | Differential Equations (22.5 ECTS) |
| | Scientific Computing (15 ECTS) |

For greater flexibility, two paths may be followed:

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

# Courses

## Courses

Share

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

**Course list for academic year 2014-2015**

*Field: Algebra and Geometry*

Commutative Algebra (Spring term)

Differentiable Manifolds (Spring term)

Number Theory (Autumn term)

Non-Commutative Algebra (Autumn term)

*Field: Discrete Mathematics and Algorithmics*

Codes and Cryptography (Autumn term)

Combinatorics (Spring term)

Discrete and Algorithmic Geometry (Autumn term)

Graph Theory (Autumn term)

*Field: Modelling in Engineering and Biomedical Sciences*

Mathematical Modelling with Partial Differential Equations (Autumn term)

Computational Mechanics (Autumn term)

Mathematical Models in Biology (Autumn term)

*Field: Differential Equations*

Quantitative and Qualitative Methods in Dynamical Systems (Autumn term)

Hamiltonian Systems (Spring term)

Advanced course in Partial Differential Equations (Spring term)

*Field: Scientific Computing*

Numerical Methods for Dynamical Systems (Spring term)

Numerical Methods for Partial Differential Equations (Autumn term)

Timetable for academic year 2014-2015

Exams

## Subjects MAMME

Last update: 17-06-2014

# 34950 - CALG - Commutative Algebra

Coordinating unit: 200 - FME - School of Mathematics and Statistics

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

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: FRANCESC D'ASSIS PLANAS VILANOVA

Others: FRANCESC D'ASSIS PLANAS VILANOVA - A

## Prior skills

Linear algebra, calculus, topology, analysis.

## Requirements

The two first years of a degree in mathematics.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

Teaching Classes, resolution of problems

## Learning objectives of the subject

# 34950 - CALG - Commutative Algebra

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

## Study load

| | | | |
|---|---|---|---|
| Total learning time: 187h 30m | Hours large group: | 60h | 32.00% |
| | Self study: | 127h 30m | 68.00% |

## Content

| Rings and ideals | Learning time: 12h 45m<br>Large group/Theory: 3h<br>Self study : 9h 45m |
|---|---|

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

| Modules | Learning time: 12h 45m<br>Large group/Theory: 3h<br>Self study : 9h 45m |
|---|---|

Description:
General properties of modules. Tensor product.

| Rings and modules of fractions | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|

Description:
Introduction to rings and modules of fractions

| Primary decompostion | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|

Description:
Classical primary theory. First theorems.

| Integral dependence | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|

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

| Chain conditions | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>Chain conditions on sets, modules, rings. | |

| Noetherian rings | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>They play a central role in Commutative Algebra and Algebraic Geometry. | |

| Artin rings | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>A good examples of noetherian rings. In some sense the simpliest. | |

| Discrete valuation rings | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>The next case. Noetherian rings of dimension one. | |

| Completions | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>To deal with topologies, completions, filtrations and graded rings. | |

| Dinmension theory | Learning time: 18h<br>Large group/Theory: 6h<br>Self study : 12h |
|---|---|
| Description:<br>A biref introduction to Hilbert functions and dimension theory. | |

## Qualification system

Continuous assessment, a final exam (if necessary)

## Bibliography

Basic:

Atiyah, Michael Francis; MacDonald, I. G. Introduction to commutative algebra. Reading: Addison-Wesley, 1969. ISBN 0201407515.

Reid, Miles. Undergraduate commutative algebra. Cambridge: Cambridge University Press, 1995. ISBN 0521452554.

Eisenbud, David. Commutative algebra : with a view toward algebraic geometry. Corrected 2nd. printing. New York: Springer-Verlag, 1996. ISBN 0387942696.

Kunz, Ernst. Introduction to commutative algebra and algebraic geometry. Boston: Birkhäuser, ISBN 3764330651.

Matsumura, Hideyuki. Commutative ring theory. Cambridge: Cambridge University Press, ISBN 0521259169.

Last update: 06-05-2014

# 34951 - NCA - Non-Commutative Algebra

Coordinating unit: 200 - FME - School of Mathematics and Statistics

Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
727 - MA III - Department of Applied Mathematics III

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: JOSE BURILLO PUIG

Others: JOSE BURILLO PUIG - A

## Prior skills

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

## Requirements

The basic algebra courses from the degree in mathematics.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

# 34951 - NCA - Non-Commutative Algebra

## Teaching methodology

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

## Learning objectives of the subject

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

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

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

## Study load

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

## Content

| Generalities about infinite groups | Learning time: 47h<br>Large group/Theory: 15h<br>Self study : 32h |
|---|---|

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

| The classical Dehn problems in group theory | Learning time: 25h<br>Large group/Theory: 8h<br>Self study : 17h |
|---|---|

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

| The free group | Learning time: 47h<br>Large group/Theory: 15h<br>Self study : 32h |
|---|---|

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

| Cayley graphs | Learning time: 31h<br>Large group/Theory: 10h<br>Self study : 21h |
|---|---|

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

| Hyperbolic groups | Learning time: 37h 30m<br>Large group/Theory: 12h<br>Self study : 25h 30m |
|---|---|
| Description:<br>Definition of hyperbolic groups.<br>First properties, finite generation, centralizers.<br>Characterization of hyperbolic groups as those having linear Dehn function. | |

## Qualification system

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

## Bibliography

### Basic:

Brady, Noel; Riley, T.; Short, H. The geometry of the word problem for finitely generated groups. Basel: Birkhäuser, 2007. ISBN 978-3764379490.

Ghys, E.; Haefliger, A.; Verjovsky, A. Group theory from a geometrical viewpoint : 26 March - 6 April 1990, ICTP, Trieste, Italy. Singapore: World Scientific, 1991. ISBN 978-9810204426.

Lyndon, Roger C.; Schupp, Paul E. Combinatorial group theory. 2nd ed. Berlin: Springer, 2001. ISBN 978-3540411581.

Bogopolskij, Oleg Vladimirovic. Introduction to group theory. Zürich: European Mathematical Society, 2008. ISBN 9783037190418.

### Complementary:

Epstein, David B.A. [et al.]. Word processing in groups. Boston: Jones and Bartlett, 1992. ISBN 978-0867202441.

Ghys, E.; La Harpe, P. de. Sur les groupes hyperboliques d'après Mikhael Gromov. Boston: Birkhäuser, 1990. ISBN 978-0817635084.

Last update: 13-06-2014

# 34953 - NT - Number Theory

Coordinating unit: 200 - FME - School of Mathematics and Statistics

Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
726 - MA II - Department of Applied Mathematics II

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: JORDI GUÀRDIA I RÚBIES

Others: JOSEP GONZALEZ ROVIRA - A
JORDI GUÀRDIA I RÚBIES - A

## Prior skills

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

## Requirements

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

# 34953 - NT - Number Theory

## Teaching methodology

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

## Learning objectives of the subject

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

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

## Study load

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

## Content

| | |
|---|---|
| Algebraic Number Theory | Learning time: 93h 45m<br>Theory classes: 30h<br>Self study : 63h 45m |

| | |
|---|---|
| Elliptic Curves | Learning time: 93h 45m<br>Theory classes: 30h<br>Self study : 63h 45m |

## Qualification system

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

## Regulations for carrying out activities

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

# 34953 - NT - Number Theory

## Bibliography

### Basic:

Neukirch, Jürgen. Algebraic number theory. Berlin: Springer-Verlag, 1999. ISBN 3540653996.

Silverman, Joseph H. The arithmetic of elliptic curves. 2nd ed. New York: Springer-Verlag, 2009. ISBN 9780387094939.

Silverman, Joseph H. Advanced topics in the arithmetic of elliptic curves. New York: Springer, 1994. ISBN 0387943250.

Last update: 13-06-2014

# 34954 - CC - Codes and Cryptography

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

## Teaching staff

Coordinator: MARIA PAZ MORILLO BOSCH

Others: JAVIER HERRANZ SOTOCA - A
MARIA PAZ MORILLO BOSCH - A
JORGE LUIS VILLAR SANTOS - A

## Prior skills

Basic probability, basic number theory and linear algebra

## Requirements

Undergraduate mathematics

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
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 INFORMATI0N 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, including theory and problem sessions.

## 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

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

# 34954 - CC - Codes and Cryptography

## Content

| Introduction | Learning time: 6h 15m<br>Theory classes: 2h<br>Self study : 4h 15m |
|---|---|
| Description:<br>The problem of communication. Information theory, Coding theory and Cryptographic theory | |

| Information and Entropy | Learning time: 18h 45m<br>Theory classes: 6h<br>Self study : 12h 45m |
|---|---|
| Description:<br>Uncertainty or information. Entropy. Mutual information | |

| Source codes without memory | Learning time: 12h 30m<br>Theory classes: 4h<br>Self study : 8h 30m |
|---|---|
| Description:<br>Codes. Average length. Huffman codes. Extensions of a source. Theory of an noiseless communication. Notes of compression. | |

| Channel coding | Learning time: 18h 45m<br>Theory classes: 6h<br>Self study : 12h 45m |
|---|---|
| Description:<br>Discrete channels without memory. Symmetric channels. Shannon's theorem. | |

| Block codes | Learning time: 18h 45m<br>Theory classes: 6h<br>Self study : 12h 45m |
|---|---|
| Description:<br>Hamming's distance. Detection and correction of errors. Bounds. Linear codes. | |

| Cyclic codes | Learning time: 18h 45m<br>Theory classes: 6h<br>Self study : 12h 45m |
|---|---|

**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.

| Introduction to modern cryptography | Learning time: 15h 37m<br>Theory classes: 5h<br>Self study : 10h 37m |
|---|---|

**Description:**
The setting: secure storage and symmetric key encryption. Turing machines and complexity classes. Security definitions. Adversarial models. Reductionist security proofs.

| Symmetric key cryptography | Learning time: 15h 38m<br>Theory classes: 5h<br>Self study : 10h 38m |
|---|---|

**Description:**
Symmetric key encryption. Pseudorandom generators. Block ciphers. Message authentication codes.

| Public key encryption | Learning time: 15h 37m<br>Theory classes: 5h<br>Self study : 10h 37m |
|---|---|

**Description:**
Definitions and security notions. One way functions. Probabilistic encryption. Main constructions. Homomorphic encryption. Chosen ciphertext security.

| Digital signatures | Learning time: 15h 38m<br>Theory classes: 5h<br>Self study : 10h 38m |
|---|---|

**Description:**
Security definitions. RSA and Schnorr signatures.

| Proofs of knowledge and other cryptographic protocols | Learning time: 15h 37m<br>Theory classes: 5h<br>Self study : 10h 37m |
| --- | --- |
| Description:<br>Ring signatures. Distributed signatures. Identity and attribute based protocols. | |

| Multiparty computation | Learning time: 15h 38m<br>Theory classes: 5h<br>Self study : 10h 38m |
| --- | --- |
| Description:<br>Secret sharing schemes. Unconditionally and computationally secure multiparty computation. | |

## Qualification system

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

## Regulations for carrying out activities

All the subjects are important. To pass the course it is required to fulfill all the items.

# 34954 - CC - Codes and Cryptography

## Bibliography

### Basic:

Huffman, W. Cary; Pless, Vera. Fundamentals of error-correcting codes. Cambridge: Cambridge University Press, 2003. ISBN 0521782805.

Justesen, Jorn; Hoholdt, Tom. A Course in error-correcting codes. Zürich: European Mathematical Society, 2004. ISBN 3037190019.

Xambó Descamps, Sebastián. Block error-correcting codes : a computational primer. Berlin: Springer, 2003. ISBN 3540003959.

Delfs, Hans; Knebl, Helmut. Introduction to cryptography : principles and applications. 2nd ed. Berlin: Springer, 2007. ISBN 9783540492436.

Katz, Jonathan; Lindell, Yehuda. Introduction to modern cryptography : principles and protocols. Boca Raton: Chapman & Hall, 2008. ISBN 9781584885511.

### Complementary:

Johnson, Sarah J. Iterative error correction : turbo, low-density parity-check and repeat-accumulate codes. Cambridge: Cambridge University Press, 2010. ISBN 9780521871488.

Welsh, Dominic. Codes and cryptography. Oxford: Oxford university Press, 1988. ISBN 0198532881.

Goldreich, Oded. Foundations of cryptography : basic tools. New York: Cambridge University Press, 2001. ISBN 0521791723.

Goldreich, Oded. Foundations of cryptography : basic applications. New York: Cambridge University Press, 2004. ISBN 9780521830843.

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Last update: 06-05-2014

# 34955 - COMB - Combinatorics

Coordinating unit: 200 - FME - School of Mathematics and Statistics

Teaching unit: 743 - MA IV - Department of Applied Mathematics IV
726 - MA II - Department of Applied Mathematics II

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: MARCOS NOY SERRANO

Others:
SIMEON MICHAEL BALL - A
ANNA DE MIER VINUÉ - A
MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

## Prior skills

Basic calculus and linear algebra. Notions of probability.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
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 INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

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

# 34955 - COMB - Combinatorics

## Learning objectives of the subject

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

## Study load

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

## Content

| | |
|---|---|
| **Partially ordered sets** | Learning time: 24h 40m<br>Theory classes: 4h<br>Practical classes: 4h<br>Self study : 16h 40m |
| Description:<br>Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem | |

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

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

| | |
|---|---|
| **Finite geometries** | Learning time: 18h 30m<br>Theory classes: 3h<br>Practical classes: 3h<br>Self study : 12h 30m |
| Description:<br>q-anologs of extremal problems. Segre's theorem. Blocking sets, ovals and hyperovals. | |

| Matroids | Learning time: 18h 30m<br>Theory classes: 3h<br>Practical classes: 3h<br>Self study : 12h 30m |
|---|---|
| Description:<br>Axioms. Transversal matroids. Greedy algorithms. The Tutte polynomial | |

| Probabilistic methods in combinatorics | Learning time: 18h 30m<br>Theory classes: 3h<br>Practical classes: 3h<br>Self study : 12h 30m |
|---|---|
| Description:<br>Permanents, transversals, hypergraph coloring. Monotone properties and threshold functions | |

| Ramsey theory | Learning time: 31h 40m<br>Theory classes: 5h<br>Practical classes: 5h<br>Self study : 21h 40m |
|---|---|
| Description:<br>Theorems of Ramsey and Hales-Jewett. Theorems of Schur, Van der Waerden and Rado. | |

| Enumerative combinatorics | Learning time: 32h 30m<br>Theory classes: 5h<br>Practical classes: 5h<br>Self study : 22h 30m |
|---|---|
| Description:<br>Symbolic and analytic methods. Symmetries and Pólya theory. | |

## Qualification system

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

# 34955 - COMB - Combinatorics

## Bibliography

Basic:

Alon, Noga; Spencer, Joel H.; Erdös, Paul. The probabilistic method. 3rd ed. New York: Wiley, 2008. ISBN 0471535885.

Bollobás, Béla; Andrew Thomason (eds.). Combinatorics, geometry, and probability : a tribute to Paul Erdos. Cambridge: Cambridge University Press, 1997. ISBN 0521584728.

Lint, Jacobus Hendricus van; Wilson, R. M. A Course in combinatorics. 2nd ed. Cambridge: Cambridge University Press, 2001. ISBN 0521803403.

Flajolet P.; Sedgewick R. Analytic combinatorics [on line]. Cambridge: Cambridge University Press, 2009Available on: <http://site.ebrary.com/lib/upcatalunya/docDetail.action?docID=10277515>. ISBN 9780521898065.

Graham, Ronald L.; Rotschild, B.; Spencer, J. Ramsey theory. 2nd ed. New York: John Wiley & Sons, 1990. ISBN 0471500461.

Anderson, Ian. Combinatorics of finite sets. Mineola: Dover, 2002. ISBN 0486422577.

Lovász, László. Combinatorial problems and exercices. 2nd ed. Amsterdam: North-Holland, 1993. ISBN 044481504X.

Oxley, J. G. Matroid theory. 2nd ed. Oxford: Oxford University Press, 2011. ISBN 9780199603398.

Last update: 06-05-2014

# 34956 - DG - Discrete and Algorithmic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics

Teaching unit: 726 - MA II - Department of Applied Mathematics II

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: JULIAN THORALF PFEIFLE

Others:

FERNANDO ALFREDO HURTADO DIAZ - A
JULIAN THORALF PFEIFLE - A

## Prior skills

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
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 INFORMATI0N 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.

# 34956 - DG - Discrete and Algorithmic Geometry

## 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

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

## Content

| Preliminaries | Learning time: 12h 30m<br>Theory classes: 4h<br>Self study : 8h 30m |
|---|---|

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

| Convexity | Learning time: 19h<br>Theory classes: 4h<br>Practical classes: 2h<br>Self study : 13h |
|---|---|

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

| Decompositions and arrangements | Learning time: 31h<br>Theory classes: 7h<br>Practical classes: 3h<br>Self study : 21h |
|---|---|

Description:
Subdivisions and triangulations of point sets and polygons. Visibility and motion planning. Duality. Special decompositions in dimension 2. The zone theorem. Incremental construction and randomized algorithms. Complexity. Levels and k-sets.

| Proximity Structures | Learning time: 31h<br>Theory classes: 7h<br>Practical classes: 3h<br>Self study : 21h |
|---|---|

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

| Polytopes and Subdivisions of Point Sets | Learning time: 38h<br>Theory classes: 10h<br>Practical classes: 3h<br>Self study : 25h |
|---|---|

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

| Lattice Geometry | Learning time: 24h<br>Theory classes: 6h<br>Practical classes: 2h<br>Self study : 16h |
|---|---|

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

| Symmetry | Learning time: 23h<br>Theory classes: 6h<br>Medium group/Practical: 1h<br>Self study : 16h |
|---|---|

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

| Software | Learning time: 9h<br>Laboratory classes: 2h<br>Self study : 7h |
|---|---|

Description:
Polymake, Curved Spaces, etc.

# 34956 - DG - Discrete and Algorithmic Geometry

## Qualification system

In general, there will be two or more exams during class hours, to be announced in advance. If so announced, students will also obtain marks by turning in their solutions to problems from the problem sets, and possibly presenting them at the blackboard.

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

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

# 34956 - DG - Discrete and Algorithmic Geometry

## Bibliography

### Basic:

Berg, Mark de; Cheong, Otfried; Kreveld, Marc van; Overmars, Mark. Computational geometry: algorithms and applications. 3rd ed. revised. Berlin: Springer, 2008. ISBN 9783540779735.

Boissonnat, J. D.; Yvinec, M. Algorithmic geometry. Cambridge: Cambridge University Press, 1997. ISBN 0521565294.

Conway, John Horton; Sloane, N. J. A. Sphere packings, lattices and groups. 3rd ed. Berlin: Springer, 1999. ISBN 0387985859.

Edelsbrunner, Herbert. Algorithms in combinatorial geometry. Berlín: Springer, 1987. ISBN 354013722X.

Matousek, Jirí. Lectures on discrete geometry. New York: Springer, 2002. ISBN 0387953736.

Pach, János; Agarwal, Pankaj K. Combinatorial geometry. New York: John Wiley & Sons, 1995. ISBN 0471588903.

Ziegler, Günter M. Lectures on polytopes. New York: Springer-Verlag, 1995. ISBN 038794365X.

Beck, Matthias ; Robins, Sinai. Computing the continuous discretely : integer-point enumeration in polyhedra. New York: Springer, 2007. ISBN 9780387291390.

### Complementary:

Bokowski, Jürgen. Computational oriented matroids : equivalence classes of matrices within a natural framework. Cambridge: Cambridge University Press, 2006. ISBN 9780521849302.

Schurmann, Achill. Computational geometry of positive definite quadratic forms : polyhedral reduction theories, algorithms, and applications. Providence: AMS ULECT-48, 2009. ISBN 9780821847350.

Weeks, Jeffrey R. The shape of space. 2nd. ed. New York: M. Dekker, 2002. ISBN 0824707095.

Richter-Gebert, Jürgen. Perspectives on projective geometry: a guided tour through real and complex geometry [on line]. Berlin: Springer, 2011 [Consultation: 23/05/2013]. Available on: <http://cataleg.upc.edu/record=b1390337~S1*cat>. ISBN 9783642172854.

### Others resources:

#### Audiovisual material

Mathfilm festival 2008 [Enregistrament vídeo]: a collection of mathematical videos. Berlin : Springer, 2008

Videomath Festival at International Congress of Mathematicians, Berlin, Germany 1998 [Enregistrament vídeo] / edited and produced Hans Christian Hege, Konrad Polthier. [Berlin] : Springer, 1998

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

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

Last update: 06-05-2014

# 34957 - GT - Graph Theory

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

## Teaching staff

Coordinator: ORIOL SERRA ALBO

Others:
MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

## Prior skills

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

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

## Learning objectives of the subject

Application of spectral techniques to the study of graphs.

# 34957 - GT - Graph Theory

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

## Study load

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

## Content

### Spectral techniques in Graph Theory

Degree competences to which the content contributes:

Description:
Adjacency and Laplacian matrix. Spectral properties. Cospectral graphs. Graph invariants and spectral properties: chromatic number, Cheeger constant, expansion properties, maxcut, bisection width. The matrix tree theorem. Random walks in graphs. Shannon capacity.

Specific objectives:

### Symmetries in graphs

Degree competences to which the content contributes:

### Minors and treewidth

Degree competences to which the content contributes:

### Graphs on surfaces

Degree competences to which the content contributes:

### Graph homomorphisms

Degree competences to which the content contributes:

### Random graphs

Degree competences to which the content contributes:

### Extremal Graph Theory

Learning time: 75h

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

# 34957 - GT - Graph Theory

## 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 forthe evaluation of the final exam.

## Bibliography

Basic:

Biggs, Norman L. Algebraic graph theory. 2nd ed. New York: Cambridge University Press, 1993. ISBN 0521458978.

Kolchin, V. F. Random graphs. Cambridge: Cambridge University Press, 1999. ISBN 0521440815.

Chung, Fan R. K. Spectral Graph Theory. Providence: American Mathematical Society, 1997. ISBN 0821803158.

Diestel, Reinhard. Graph theory. 3rd ed. Berlin: Springer, 2005. ISBN 3540261826.

Hell, Pavol; Nesetril, Jaroslav. Graphs and homomorphisms. Oxford: Oxford University Press, 2004. ISBN 0198528175.

Last update: 06-05-2014

# 34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics

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

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## 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.

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N 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

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

## Learning objectives of the subject

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

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

## Study load

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

# 34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

## Content

| | |
|---|---|
| 1 Heat conduction and diffusion | Learning time: 37h 30m<br>Theory classes: 12h<br>Self study : 25h 30m |
| 2 Potentials in physics and technology | Learning time: 37h 30m<br>Theory classes: 12h<br>Self study : 25h 30m |
| 3 Transients in continuous media | Learning time: 37h 30m<br>Theory classes: 12h<br>Practical classes: 25h 30m |
| 4 Population dynamics | Learning time: 37h 30m<br>Theory classes: 12h<br>Practical classes: 25h 30m |
| 5 Distributions of particles | Learning time: 37h 30m<br>Theory classes: 12h<br>Practical classes: 25h 30m |

## Qualification system

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

# 34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

## Bibliography

### Basic:

Howison, Sam. Practical applied mathematics : modelling, analysis, approximation. New York: Cambridge University Press, 2005. ISBN 0521603692.

Friedman, A.; Litman, W. Industrial mathematics : a course in solving real-world problems. Philadelphia: SIAM, 1994. ISBN 0898713242.

Ockendon, J.R. [et al.]. Applied partial differential equations. Revised ed. Oxford: Oxford University Press, 2003. ISBN 0198527713.

Fowler, A.C. Mathematical models in the applied sciences. Cambridge: Cambridge University Press, 1997. ISBN 0521467039.

### Complementary:

Crank, John. The Mathematics of diffusion. 2nd ed. Oxford: Clarendon Press, 1975. ISBN 0198534116.

Tijonov, A.; Samarsky, A. Ecuaciones de la física matemática. 3ª ed. Moscú: Mir, 1983.

Salsa, Sandro. Partial differential equations in action : from modelling to theory [on line]. Milan [etc.]: Springer, cop. 2008Available on: < http://site.ebrary.com/lib/upcatalunya/docDetail.action?docID=10231792&p00>. ISBN 9788847007512.

Last update: 13-06-2014

# 34959 - CM - Computational Mechanics

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

## Teaching staff

Coordinator: JOSE JAVIER MUÑOZ ROMERO

Others: JOSE JAVIER MUÑOZ ROMERO - A

## Prior skills

Basic knowledge of numerical methods
Basic knowledge of partial differential equations

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

Three elements will be combined: theory classes, where the main concepts will be presented;
practical classes in the computer room, with emphasis on the computational aspects; and lists of problems. Students will work on these problems individually or in pairs.

# 34959 - CM - Computational Mechanics

## Learning objectives of the subject

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

## Study load

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

## Content

| CONTINUUM MECHANICS | Learning time: 31h 15m<br>Large group/Theory: 8h<br>Medium group/Practical: 2h<br>Self study : 21h 15m |
|---|---|

Description:
Motivation. Definition of continuous media. Equation of motion: Eulerian and Lagrangian descriptions. Time derivatives. Strains: deformation gradient, Green and Euler-Almansi tensors; elongation and shear; small strains. Stresses: body and surface forces; Cauchy stress tensor.
Balance equations: Reynolds transport theorem; mass balance; momentum balance. Constitutive equations. Applications.

| COMPUTATIONAL ELASTICITY | Learning time: 31h 15m<br>Large group/Theory: 8h<br>Medium group/Practical: 2h<br>Self study : 21h 15m |
|---|---|

Description:
Basic concepts and motivation. Elastic constitutive equation. Displacement formulation: Navier equations. Two-dimensional elasticity: plane stresses, plane strains and axisymmetry. Weak form of the elastic problem. Finite element discretisation. Computational aspects. Applications.

| COMPUTATIONAL DYNAMICS | Learning time: 31h 15m<br>Large group/Theory: 8h<br>Medium group/Practical: 2h<br>Self study : 21h 15m |
|---|---|

Description:
Weak form. Dynamic equation. Space discretisation (finite elements) and time discretisation. Solution methods: generalised eigen value problem and direct time integration. Euler, Runge Kutta and Newmark methods. Stability, consistency and accuracy of numerical techniques in elastodynamics. Applications.

| COMPUTATIONAL PLASTICITY | Learning time: 31h 15m<br>Large group/Theory: 8h<br>Medium group/Practical: 2h<br>Self study : 21h 15m |
|---|---|

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

| COMPUTATIONAL FLUID DYNAMICS | Learning time: 31h 15m<br>Large group/Theory: 8h<br>Medium group/Practical: 2h<br>Self study : 21h 15m |
|---|---|

Description:
Basic concepts and motivation. Rate-of-deformation and spin tensors. Constitutive equation for Newtonian fluids. Euler equations for inviscid flow. Navier-Stokes equations for viscous flow in strong form and in weak form. Reynolds number. Stokes flow and potential flow. Applications.

| COMPUTATIONAL METHODS FOR WAVE PROBLEMS | Learning time: 31h 15m<br>Theory classes: 8h<br>Practical classes: 2h<br>Self study : 21h 15m |
|---|---|

Description:
Basic concepts and motivation.
Acoustics: the wave equation. The scalar Helmholtz equation. Vibroacoustics: acoustic fluid-elastic solid interaction. Computational aspects. Applications.
Electromagnetism: the Maxwell equations. Electrodynamics. The vectorial Helmholtz equation. Computational aspects. Applications.

## Qualification system

Exam and assigned problems.

# 34959 - CM - Computational Mechanics

## Bibliography

### Basic:

Clough, Ray W.; Penzien, J. Dynamics of structures. 2nd ed. New York: McGraw-Hill, 1993. ISBN 0071132414.

Donea, Jean M.; Huerta, A. Finite element methods for flow problems. Chichester: John Wiley & Sons, 2003. ISBN 0471496669.

Ihlenburg, F. Finite element analysis of acoustic scattering [on line]. New York: Springer-Verlag, 1998Available on: <http://link.springer.com/book/10.1007%2Fb98828>. ISBN 0387983198.

Mase, G. Thomas; Mase, George E. Continuum mechanics for engineers. 3rd ed. Boca Raton: CRC, 2010.

### Complementary:

Bathe, Klaus-Jürgen. Finite element procedures. New Jersey: Prentice-Hall, 1996. ISBN 0133014584.

Bonet, Javier; Wood, R. D. Nonlinear continuum mechanics for finite element analysis. 2nd ed. Cambridge: Cambridge University Press, 2008. ISBN 9780521838702.

Marsden, Jerrold E.; Hugues, Thomas J. R. Mathematical foundations of elasticity. New York: Dover, 1994. ISBN 0486678652.

Simo, J. C.; Hughes, T. J. R. Computational inelasticity [on line]. New York: Springer-Verlag, 1998Available on: <http://link.springer.com/book/10.1007/b98904>.

Zienkiewicz O. C.;Taylor, R. L. The finite element method. 6th ed. Oxford: Butterworth Heinemann, 2005.

Last update: 13-06-2014

# 34960 - MMB - Mathematical Models in Biology

Coordinating unit: 200 - FME - School of Mathematics and Statistics

Teaching unit: 726 - MA II - Department of Applied Mathematics II
725 - MA I - Department of Applied Mathematics I

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: ANTONI GUILLAMON GRABOLOSA

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

Casanellas Rius, Marta
Casanellas Rius, Marta

## Prior skills

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

## Requirements

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning

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 INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

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

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

## Learning objectives of the subject

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

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

## Study load

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

# 34960 - MMB - Mathematical Models in Biology

## Content

### Models of Population Dynamics

Learning time: 37h 30m

Large group/Theory: 6h
Small group/Laboratory: 6h
Self study : 25h 30m

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: 75h

Large group/Theory: 12h
Small group/Laboratory: 12h
Self study : 51h

Description:

1. Brief introduction to genomics (genome, gen structure, genetic code...). Genome databases online.
2. Phylogenetics: Markov models of molecular evolution (Jukes-Cantor, Kimura, Felsenstein hierarchy...), phylogenetic trees, branch lengths. Phylogenetic tree reconstruction (distance and character based methods).
3. Genomics: Markov chains and Hidden Markov models for gene prediction. Tropical arithmetics and Viterbi algorithm. Forward and Expectation-Maximization algorithms.
4. Multiple sequence alignment: dynamical programming, tropical arithmetics and Pair-HMMs

### Mathematical Models in Neurohysiology

Learning time: 56h 15m

Large group/Theory: 9h
Small group/Laboratory: 9h
Self study : 38h 15m

Description:

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

# 34960 - MMB - Mathematical Models in Biology

| Biological networks | Learning time: 18h 45m<br>Large group/Theory: 3h<br>Small group/Laboratory: 3h<br>Self study : 12h 45m |
|---|---|

Description:
1. Complex networks in biology.
2. Networks of neurons.

## Qualification system

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

# 34960 - MMB - Mathematical Models in Biology

## Bibliography

### Basic:

Allman, Elizabeth S.; Rhodes, John A. Mathematical models in biology: an introduction. Cambridge: Cambridge University Press, 2004. ISBN 9780521819800.

Istas, Jacques. Mathematical modeling for the life sciences [on line]. Berlin: Springer, 2005Available on: <http://dx.doi.org/10.1007/3-540-27877-X>. ISBN 354025305X.

Murray, J.D. Mathematical biology [on line]. 3rd ed. Berlin: Springer, 2002Available on: <http://cataleg.upc.edu/record=b1305682~S1*cat>. ISBN 978-0-387-95223-9.

Pachter, Lior; Sturmfels, Bernd. Algebraic statistics for computational biology. Cambridge: Cambridge University Press, 2005. ISBN 0521857007.

Keener, James P.; Sneyd, James. Mathematical physiology. Vol 1. 2nd ed. New York: Springer Verlag, 2009. ISBN 9780387758466.

Izhikevich, Eugene M. Dynamical systems in neuroscience : the geometry of excitability and bursting. Cambridge: MIT Press, 2007. ISBN 0262090430.

Ermentrout, Bard G.; Terman, David H. Mathematical foundations of neuroscience. New York: Springer, 2010. ISBN 978-0-387-87708-2.

### Complementary:

Stein, William A. [et al.]. Sage mathematics software (Version 4.4.2) [on line]. 2010 [Consultation: 23/11/2012]. Available on: <http://www.sagemath.org/>.

Durbin, Richard [et al.]. Biological sequence analysis : probabilistic models of proteins and nucleic acids. Cambridge: Cambridge University Press, 1998. ISBN 0521629713.

Feng, Jianfeng. Computational neuroscience : a comprehensive approach [on line]. Boca Raton: Chapman & Hall/CRC, 2004 [Consultation: 23/11/2012]. Available on: <http://nba.uth.tmc.edu/homepage/cnjclub/2007summer/renart_chapter.pdf>.

Felsenstein, J. PHYLIP [on line]. [Consultation: 23/11/2012]. Available on: <http://evolution.genetics.washington.edu/phylip.html>.

European Bioinformatics Institute; Wellcome Trust Sanger Institute. Ensembl project [on line]. [Consultation: 23/11/2012]. Available on: <http://www.ensembl.org>.

Last update: 13-06-2014

# 34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

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

## Teaching staff

Coordinator: MARIA TERESA MARTINEZ-SEARA ALONSO

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

## Opening hours

Timetable: Make an appointment by email

## Prior skills

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

# 34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

## Teaching methodology

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

## Learning objectives of the subject

## Study load

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

# 34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

## Content

| -Invariant objects in Dynamical Systems | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|

Description:
Continuous and dicrete Dynamical Systems. Poincaré map. Local behaviour of hyperbolic invariant objects. Invariant manifolds. Central manifold. Local bifurcations.

| -Perturbation theory in Dynamical Systems | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|

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

| Discrete Dynamical Systems | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|

Description:
Discrete systems. Denjoy theorem. Generic properties. Sarkovskii theorem.

| -Homoclinic points and chaotic Dynamics | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|

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

| -Normal forms | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|
| Description:<br>Poincaré-Dulac normal forms. Convergence: Poincaré and Siegel domains.<br>Hamiltoniane normal forms. Bifurcations. Lie series. Construction of<br>algebraic and analytic manipulators. | |

| -Normal forms: its aplication to stability in Dynamical Systems | Learning time: 20h<br>Theory classes: 5h<br>Practical classes: 5h<br>Other activities: 10h |
|---|---|
| Description:<br>KAM (Kolmogorov-Arnold-Moser) theory, twist theorem. Small divisors and diophantic inequalities. Efective stability and Nekhoroshev theorem.<br>Splitting of separatrices, Melnikov potential. Arnold diffusion. | |

| Introduction to non-smooth systems | Learning time: 4h<br>Theory classes: 4h |
|---|---|
| Description:<br>We will provide several examples of non-smooth systems and give the basic theory for them. | |

## Qualification system

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

## Regulations for carrying out activities

There are no exams.

# 34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

## Bibliography

Basic:

Arrowsmith, D. K; Place, C. M. An Introduction to dynamical systems. Cambridge [England] ; New York: Cambridge University Press, 1990. ISBN 0-521-30362-1.

Guckenheimer, John; Holmes, Philip. Nonlinear oscillations, dynamical systems, and bifurcations of vector fields. New York, NY [etc.]: Springer-Verlag, 1983. ISBN 0-387-90819-6.

Di Bernardo, Mario. Piecewise-smooth dynamical systems. London: Springer-Verlag, 2007. ISBN 978-1-84628-039-9.

Last update: 13-06-2014

# 34962 - HS - Hamiltonian Systems

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

## Teaching staff

Coordinator: AMADEU DELSHAMS I VALDES

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

## Prior skills

Knowledge of calculus, algebra and ordinary differential equations.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
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 INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

Standard exposition in front of the blackboard, resolution of exercices, completion of a project and/or attendance to the JISD summer school http://www.ma1.upc.edu/recerca/jisd

## Learning objectives of the subject

Last update: 13-06-2014

# 34962 - HS - Hamiltonian Systems

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

## Study load

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

# 34962 - HS - Hamiltonian Systems

## Content

| Hamiltonian formalism | Learning time: 26h<br>Theory classes: 4h<br>Practical classes: 4h<br>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<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|

Description:
Lagrangian systems. Configuration manifold, tangent and cotangent bundles. Systems with symmetries, Noether theorem. Principle of minimal action.

| Integrable and quasi-integrable Hamiltonian systems | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|

Description:
Complete integrability and Liouville-Arnold theorem. Quasi-periodic flows on a torus, resonances. Examples of quasi-integrable systems. Twist maps and billiards. Analytic non-integrability.

| Invariant objects of dynamical systems | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>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<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|
| Description:<br>Classical perturbation theory. Perturbations of homoclinic orbits in the plane: Melnikov method. | |

| Homoclinic points and chaotic dynamics | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|
| Description:<br>Homoclinic points and bifurcations. Hyperbolic sets and transverse homoclinic points: systems with chaotic dynamics. Newhouse phenomenon. | |

| Normal forms | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|
| Description:<br>Poincaré-Dulac normal forms. Convergence: Poincaré and Siegel domains. Hamiltonian normal forms. Bifurcstions. Lie series. Construction of algebraic manipulators. | |

| Stability of dynamical systems and Hamiltonian systems | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|
| Description:<br>KAM theory (Kolmogorov-Arnold-Moser), twist theorem. Small divisors and Diophantine inequalities. Effective stability and Nekhoroshev theorem. Splitting of separatrices, Melnikov potential. Arnold diffusion. | |

| Discrete dynamical systems | Learning time: 13h<br>Theory classes: 2h<br>Practical classes: 2h<br>Self study : 9h |
|---|---|
| Description:<br>Discrete systems. Denjoy theorem. Generic properties. Sarkovskii theorem. | |

| Interactions between Dynamical Systems and Partial Differential Equations | Learning time: 57h 30m<br>Theory classes: 20h<br>Self study : 37h 30m |
|---|---|
| Description:<br>Summer School and Research workshop on topics between Dynamical Systems and Partial Differential Equations | |

## Planning of activities

### JISD summer school

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

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

## Qualification system

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

# 34962 - HS - Hamiltonian Systems

## Bibliography

### Basic:

Arnol'd, V. I.; Kozlov, Valerii V.; Neishtadt, Anatoly I. Mathematical aspects of classical and celestial mechanics [on line]. 3rd ed. Berlin: Springer-Verlag, 2006Available on: <http://dx.doi.org/10.1007/978-3-540-48926-9>. ISBN 3540282467.

Meyer, Kenneth R.; Hall, Glen R.; Offin, Dan. Introduction to Hamiltonian dynamical systems and the n-body problem. 2nd ed. New York: Springer-Verlag, 2009. ISBN 978-0-387-09723-7.

Treschev, Dmitry; Zubelevich, Oleg. Introduction to the perturbation theory of Hamiltonian systems. Berlin: Springer Verlag, 2010. ISBN 978-3-642-03027-7.

Bountis, Tassos ; Skokos, Haris. Complex Hamiltonian dynamics. Springer, 2012. ISBN 9783642273049.

Dumas, H Scott. The KAM Story: A Friendly Introduction to the Content, History, and Significance of Classical Kolmogorov-Arnold-Moser Theory. World Scientific Publishing, 2014. ISBN 978-981-4556-58-3.

Berti, Massimiliano. Nonlinear Oscillations of Hamiltonian PDEs. Boston, MA: Birkhäuser Boston, Inc., 2007. ISBN 978-0-8176-4680-6.

### Others resources:

Hyperlink

Grup de sistemes dinàmics

https://recerca.upc.edu/sd

pàgina web del Grup de Sistemes Dinàmics de la UPC on es descriuen diversos projectes i els investigadors que hi treballen així com diverses activitats relacionades

Last update: 13-06-2014

# 34963 - ACPDE - Advanced Course in Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics

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

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: MARIA DEL MAR GONZALEZ NOGUERAS

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

## Prior skills

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

## Requirements

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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 INFORMATI0N 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.

Last update: 13-06-2014

# 34963 - ACPDE - Advanced Course in Partial Differential Equations

## Teaching methodology

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

## Learning objectives of the subject

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

## Study load

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

# 34963 - ACPDE - Advanced Course in Partial Differential Equations

## Content

| Classical methods for the Poisson and heat equations | Learning time: 47h<br>Theory classes: 15h<br>Self study : 32h |
| --- | --- |

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

| Sobolev spaces and variational methods | Learning time: 47h<br>Theory classes: 15h<br>Self study : 32h |
| --- | --- |

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

| Evolution equations | Learning time: 46h 45m<br>Theory classes: 15h<br>Self study : 31h 45m |
| --- | --- |

**Description:**
Prabolic equations. Galerkin method. Semigroups. Nonlinear conservation laws.

| Introduction to nonlinear PDEs | Learning time: 46h 45m<br>Theory classes: 15h<br>Self study : 31h 45m |
| --- | --- |

**Description:**
Calculus of Variations. Nonlinear eigenvalue problems. Semi-linear elliptic equations.

## Qualification system

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

# 34963 - ACPDE - Advanced Course in Partial Differential Equations

## Bibliography

### Basic:

Evans, Lawrence Craig. Partial differential equations. Providence, Rhode Island: American Mathematical Society, 1998. ISBN 0821807722.

Salsa, Sandro. Partial differential equations in action : from modelling to theory [on line]. Milan: Springer, 2008Available on: <http://site.ebrary.com/lib/upcatalunya/docDetail.action?docID=10231792&p00>. ISBN 9788847007512.

Brézis, H. Análisis funcional : teoría y aplicaciones. Madrid: Alianza, 1984. ISBN 8420680885.

### Complementary:

Struwe, Michael. Variational methods : applications to nonlinear partial differential equations and hamiltonian systems. 2nd rev. and substantially expanded ed. Berlin: Springer, 1996. ISBN 3540520228.

Gilbarg, David; Trudinger, Neil S. Elliptic partial differential equations of second order. 2nd ed., rev. third printing. Berlin: Springer-Verlag, 1998. ISBN 354013025X.

Zuily, C. Problems in distributions and partial differential equations. Paris: North-Holland, 1988.

Necas, Jindrich. Introduction to the theory of nonlinear elliptic equations. Chichester: John Wiley & Sons, 1986. ISBN 0471908940.

Last update: 06-05-2014

# 34964 - NMDS - Numerical Methods for Dynamical Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics

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

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: MARIA MERCEDES OLLE TORNER

Others:

MARIA MERCEDES OLLE TORNER - A

## Prior skills

Good knowledge of a programming language.

## Requirements

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

# 34964 - NMDS - Numerical Methods for Dynamical Systems

## Teaching methodology

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

## Learning objectives of the subject

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

## Study load

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

# 34964 - NMDS - Numerical Methods for Dynamical Systems

## Content

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

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

| | |
|---|---|
| Computation and stability of fixed points. Vector fields and maps. Implementation and examples. | Learning time: 10h<br>Theory classes: 5h<br>Practical classes: 5h |

| | |
|---|---|
| Computation and stability of periodic orbits. Implementation, continuation of families, bifurcations. Multiple shooting. | Learning time: 10h<br>Theory classes: 5h<br>Practical classes: 5h |

| | |
|---|---|
| Computation of tori: representation, computation and continuation. Implementation and examples. | Learning time: 15h<br>Theory classes: 7h 30m<br>Practical classes: 7h 30m |

| | |
|---|---|
| Analysis of bifurcations. Some examples. | Learning time: 15h<br>Theory classes: 7h 30m<br>Practical classes: 7h 30m |

-

Degree competences to which the content contributes:

# 34964 - NMDS - Numerical Methods for Dynamical Systems

## Qualification system

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

## Regulations for carrying out activities

No rules, in principle.

## Bibliography

### Basic:

Lichtenberg, Allan J; Lieberman, M. A. Regular and chaotic motion. New York: Springer-Verlag, 1983. ISBN 0387907076.

Press, William H. Numerical recipes in C : the art of scientific computing. 2nd. Cambridge: Cambridge University Press, 1992.

Arrowsmith, D. K; Place, C. M. An introduction to dynamical systems. Cambridge: Cambridge University Press, 1990. ISBN 0521303621.

Particular articles related to the topics of the course and some notes from suitable web pages.

Last update: 06-05-2014

# 34965 - NMPDE - Numerical Methods for Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics

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

Academic year: 2014

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

ECTS credits: 7,5 Teaching languages: English

## Teaching staff

Coordinator: MARCO DISCACCIATI

Others:

MARCO DISCACCIATI - A

## Prior skills

Basics on numerical methods, differential equations and calculus.

## Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N 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

Last update: 06-05-2014

# 34965 - NMPDE - Numerical Methods for Partial Differential Equations

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 | Learning time: 12h<br>Theory classes: 4h<br>Practical classes: 2h<br>Self study : 6h |

| | |
|---|---|
| Elliptic partial differential equations | Learning time: 32h<br>Theory classes: 4h<br>Practical classes: 4h<br>Self study : 24h |

| | |
|---|---|
| The finite element method | Learning time: 32h<br>Theory classes: 4h<br>Practical classes: 4h<br>Self study : 24h |

| | |
|---|---|
| Approximation of elliptic PDEs by the Galerkin finite elements method | Learning time: 33h 30m<br>Theory classes: 4h<br>Practical classes: 4h<br>Self study : 25h 30m |

| | |
|---|---|
| Numerical approximation of the Navier-Stokes equations | Learning time: 44h<br>Theory classes: 10h<br>Practical classes: 10h<br>Self study : 24h |

| | |
|---|---|
| Introduction to domain decomposition methods | Learning time: 34h<br>Theory classes: 6h<br>Practical classes: 4h<br>Self study : 24h |

# 34965 - NMPDE - Numerical Methods for Partial Differential Equations

## Qualification system

Continuous assessment: during the course students will be required to carry out two projects. The projects must be done individually and they constitute the 50% of the final mark.

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

## Bibliography

### Basic:

Hughes, Thomas J. R. The finite element method : linear static and dynamic finite element analysis. Englewood Cliffs, NJ: Prentice-Hall International, 1987. ISBN 0133170179.

Wait, R.; Mitchell, A. R. Finite elements analysis and applications. Chichester: John Wiley, 1985. ISBN 0471906778.

Zienkiewicz, O.C.; Taylor, R. L. The finite element method. 6th ed. Oxford: Butterworth Heinemann, 2005.

Donea, Jean M; Huerta, A. Finite element methods for flow problems. Chichester: John Wiley & Sons, 2003. ISBN 0471496669.

Ainsworth, M.; Oden, J. T. A posteriori error estimation in finite element analysis. New York: John Wiley & sons, 2000. ISBN 047129411X.

### Complementary:

Hoffman, Joe D. Numerical methods for engineers and scientists. 2nd ed. rev. and exp. New York: Marcel Dekker, 2001. ISBN 0824704436.

Johnson, Claes. Numerical solution of partial differential equations by the finite element. Mineola, New York: Dover Publications, 2009. ISBN 9780486469003.

Strang, G.; Fix, G. J. An analysis of the finite element method. Englewood Cliffs, NJ: Prentice-Hall, 1973. ISBN 0130329460.

Trefethen, Lloyd N.; Bau, David. Numerical linear algebra. Philadelphia: SIAM, 1997. ISBN 9780898713619.

Last update: 17-06-2014

# 34966 - VD - Differentiable Manifolds

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

## Teaching staff

Coordinator: FRANCESC XAVIER GRACIA SABATE

Others: FRANCESC XAVIER GRACIA SABATE - A

## Prior skills

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

## Degree competences to which the subject contributes

Specific:

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

Transversal:

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 INFORMATI0N 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.

# 34966 - VD - Differentiable Manifolds

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

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

# 34966 - VD - Differentiable Manifolds

## Content

| Basic differential geometry | Learning time: 37h 30m<br>Large group/Theory: 12h<br>Self study : 25h 30m |
|---|---|

| Riemannian manifolds and symplectic manifolds | Learning time: 37h 30m<br>Large group/Theory: 12h<br>Self study : 25h 30m |
|---|---|

| Lie groups and Lie algebras | Learning time: 50h<br>Large group/Theory: 16h<br>Self study : 34h |
|---|---|

| Supplements on topology and analysis | Learning time: 37h 30m<br>Large group/Theory: 12h<br>Self study : 25h 30m |
|---|---|

| Applications | Learning time: 25h<br>Large group/Theory: 8h<br>Self study : 17h |
|---|---|

## 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.

# 34966 - VD - Differentiable Manifolds

## Bibliography

### Basic:

Lee, John M. Introduction to smooth manifolds. New York: Springer-Verlag, 2003. ISBN 0387954481.

Bott, Raoul; Tu, Loring W. Differential forms in algebraic topology. New York: Springer-Verlag, 1982. ISBN 0387906134.

Duistermaat, J. J. ; Kolk, Johan A. C. Lie groups. Berlin: Springer-Verlag, 2000. ISBN 3540152938.

Greub, W. H.; Halperin, S.; Vanstone, R. Connections, curvature and cohomology (vol. I). New York: Academic Press, 1972-1976.

Greub, W. H.; Halperin, S.; Vanstone, R. Connections, curvature and cohomology (vol. II). New York: Academic Press, 1972-1976.

### Complementary:

Lee, John M. Riemannian manifolds : an introduction to curvature [on line]. New York: Springer, 1997 [Consultation: 05/06/2012]. Available on: <http://link.springer.com/book/10.1007%2Fb98852>. ISBN 038798271X.

Massey, William S. Algebraic topology: an introduction. New York: Springer-Verlag, cop. 1977. ISBN 0387902716.

Warner, Frank W. Foundations of differentiable manifolds and lie groups. New York, NY [etc.]: Springer-Verlag, cop. 1971. ISBN 0387908943.

Dieudonné, Jean. Éléments d'analyse (vol. II-V). Paris: Gauthier-Villars, cop. 2003. ISBN 2876472155.

Olver, Peter J. Applications of Lie groups to differential equations. New York: Springer-Verlag, 1986. ISBN 0387940073.