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   Curriculum
   Competencies
   Professional opportunities

Program
   Study program
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   Master thesis

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General information MAMME

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

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

The curriculum comprises a total of 60 ECTS, divided in 45 ECTS for courses and 15 ECTS for the master’s thesis. It is intended to be completed in one academic year. In addition, MAMME offers the possibility of registering up to 22.5 ECTS in other masters in mathematics or statistics, or in other UPC master programs, opening the path for an interdisciplinary curriculum based on selected courses in masters in engineering and applied sciences. See the MAMME focus proposals at http://mamme.masters.upc.edu/en/[9].

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

Introduction  Admission  Curriculum  Professional opportunities  Organisation

Duration and start date
One academic year; 60 ECTS credits. Starting September and February

Timetable and delivery
Afternoons  Face-to-face

Fees and grants
Approximate fees for the master’s degree €3,147 (€4,720 for non-EU residents).
This master has been selected in the Masters of Excellence scholarship grant program the Catalunya La Pedrera Foundation for the year 2016-2017 course. More information at the Foundation website.
More information about fees and payment options.
More information about grants and loans.

Language of instruction
English

Location
School of Mathematics and Statistics (FME)

Official degree
Recorded in the Ministry of Education’s degree register.

Double-degree agreements
Double-degree pathways with universities around the world
- Master’s degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Applied Mathematics (Illinois Institute of Technology). (Only FME students to Illinois, not vice versa)
General requirements

Academic requirements for admission to master’s degrees

Specific requirements

This master is addressed to students with good abstract reasoning, interest in problem solving, strong work habits and a liking for mathematics.

A scientific background is required, with basic mathematical foundations. For 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.

Places

30

Pre-enrolment

Pre-enrolment period open.
How to pre-enrol

Enrolment

How to enrol

Legalisation of foreign documents

All documents issued in non-EU countries must be legalised and bear the corresponding apostille.
## First semester

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codes and Cryptography</td>
<td>7.5</td>
</tr>
<tr>
<td>Differentiable Manifolds</td>
<td>7.5</td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td>7.5</td>
</tr>
<tr>
<td>Graph Theory</td>
<td>7.5</td>
</tr>
<tr>
<td>Mathematical Modelling with Partial Differential Equations</td>
<td>7.5</td>
</tr>
<tr>
<td>Non-Commutative Algebra</td>
<td>7.5</td>
</tr>
<tr>
<td>Number Theory</td>
<td>7.5</td>
</tr>
<tr>
<td>Numerical Methods for Dynamical Systems</td>
<td>7.5</td>
</tr>
<tr>
<td>Numerical Methods for Partial Differential Equations</td>
<td>7.5</td>
</tr>
<tr>
<td>Quantitative and Qualitative Methods in Dynamical Systems</td>
<td>7.5</td>
</tr>
</tbody>
</table>

## Second semester

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Course in Partial Differential Equations</td>
<td>7.5</td>
</tr>
<tr>
<td>Algebraic Geometry</td>
<td>7.5</td>
</tr>
<tr>
<td>Combinatorics</td>
<td>7.5</td>
</tr>
<tr>
<td>Commutative Algebra</td>
<td>7.5</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5</td>
</tr>
<tr>
<td>Hamiltonian Systems</td>
<td>7.5</td>
</tr>
<tr>
<td>Mathematical Models in Biology</td>
<td>7.5</td>
</tr>
</tbody>
</table>
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.)

Competencies

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.
Organising school
School of Mathematics and Statistics (FME)

Academic coordinator
Sonia Fernández Mández

Academic calendar
General academic calendar for bachelor’s, master’s and doctoral degrees courses

Academic regulations
Academic regulations for master’s degree courses at the UPC

Request information
- This master
- General

Name
Email *
Country *
Your question *

Privacy policy
Send
Program

Study program
MAMME courses
Master thesis
# Study program

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

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

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

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

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

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

A tutor is assigned to each student, to provide academic guidance for the selection of courses (according to the student background and interests) and for the proposal of the master thesis topic.
MAMME courses

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

Field: Algebra and Geometry
- Commutative Algebra (Spring term Q2) [not for academic year 2018-2019]
- Algebraic Geometry (Spring term Q2) [not for academic year 2019-2020]
- Differentiable Manifolds (Autumn term Q1) [not for academic year 2015-2016]
- Number Theory (Autumn term Q1) [not for academic year 2017-2018]
- Non-Commutative Algebra (Autumn term Q1) [not for academic year 2016-2017]

Field: Discrete Mathematics and Algorithmics
- Codes and Cryptography (Autumn term Q1)
- Combinatorics (Spring term Q2)
- Discrete and Algorithmic Geometry (Autumn term Q1)
- Graph Theory (Autumn term Q1)

Field: Modelling in Engineering and Biomedical Sciences
- Mathematical Modelling with Partial Differential Equations (Autumn term Q1)
- Computational Mechanics (Spring term Q2)
- Mathematical Models in Biology (Spring term Q2)

Field: Differential Equations
- Quantitative and Qualitative Methods in Dynamical Systems (Autumn term Q1)
- Hamiltonian Systems (Spring term Q2)
- Advanced course in Partial Differential Equations (Spring term Q2)

Field: Scientific Computing
- Numerical Methods for Dynamical Systems (Autumn term Q1)
- Numerical Methods for Partial Differential Equations (Autumn term Q1)
Master’s thesis

All students are required to write and defend a master thesis, usually during the second term of the academic year. It may be carried out at a research group in UPC (see the research groups associated to the PhD program in Applied Mathematics at UPC), at a research group from another university, at a research center or at a company.

A list of proposals for master thesis can be found at the FME intranet at Borsa de Projectes.

Regulations, calendar and templates

The calendar and the academic regulations for the master’s thesis can be found at the FME web page.

Templates for the document of the master thesis can be downloaded here:
- LaTeX template
- Cover page

Forthcoming defenses

A list of forthcoming presentations of master’s thesis can be found at this link.
Subjects MAMME
<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>34950</td>
<td>Commutative Algebra</td>
</tr>
<tr>
<td>34952</td>
<td>Algebraic Geometry</td>
</tr>
<tr>
<td>34953</td>
<td>Number Theory</td>
</tr>
<tr>
<td>34954</td>
<td>Codes and Cryptography</td>
</tr>
<tr>
<td>34955</td>
<td>Combinatorics</td>
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<td>34956</td>
<td>Discrete and Algorithmic Geometry</td>
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<td>34957</td>
<td>Graph Theory</td>
</tr>
<tr>
<td>34958</td>
<td>Mathematical Modelling with Partial Differential Equations</td>
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<tr>
<td>34959</td>
<td>Computational Mechanics</td>
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<td>34960</td>
<td>Mathematical Models in Biology</td>
</tr>
<tr>
<td>34961</td>
<td>Quantitative and Qualitative Methods in Dynamical Systems</td>
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<td>34962</td>
<td>Hamiltonian Systems</td>
</tr>
<tr>
<td>34963</td>
<td>Advanced Course in Partial Differential Equations</td>
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<tr>
<td>34964</td>
<td>Numerical Methods for Dynamical Systems</td>
</tr>
<tr>
<td>34965</td>
<td>Numerical Methods for Partial Differential Equations</td>
</tr>
<tr>
<td>34966</td>
<td>Differentiable Manifolds</td>
</tr>
</tbody>
</table>
34950 - CALG - Commutative Algebra

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5
Teaching languages: English

Teaching staff

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

Prior skills

Linear algebra, algebraic structures, topology.

Requirements

The two first years of a degree in mathematics.

Degree competences to which the subject contributes

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

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

Teaching methodology

Teaching Classes, resolution of problems

Learning objectives of the subject
Basic course in Commutative Algebra.
An introduction to the theory of rings, ideals and modules.
Some basics on local algebra.

**Study load**

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

<table>
<thead>
<tr>
<th>Title</th>
<th>Learning time: 28h 20m</th>
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<tbody>
<tr>
<td><strong>Rings and ideals</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Basics on ring theory and ideals. Rings of fractions. Primary decomposition. Chain conditions. Noetherian and Artinian rings.</td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td>28h 20m</td>
</tr>
<tr>
<td><strong>Theory classes:</strong></td>
<td>15h</td>
</tr>
<tr>
<td><strong>Self study:</strong></td>
<td>13h 20m</td>
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</table>

<table>
<thead>
<tr>
<th>Title</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Modules</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>General properties of modules. Modules of fractions. Chain conditions. Homomorphisms and tensor product.</td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td>24h</td>
</tr>
<tr>
<td><strong>Theory classes:</strong></td>
<td>12h</td>
</tr>
<tr>
<td><strong>Self study:</strong></td>
<td>12h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Learning time: 24h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Algebraic varieties</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>The spectrum of a ring. Zariski topology.</td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td>24h</td>
</tr>
<tr>
<td><strong>Theory classes:</strong></td>
<td>12h</td>
</tr>
<tr>
<td><strong>Self study:</strong></td>
<td>12h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Learning time: 24h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction to homological algebra</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Categories and functors. Complexes of modules. Derived functors.</td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td>24h</td>
</tr>
<tr>
<td><strong>Theory classes:</strong></td>
<td>12h</td>
</tr>
<tr>
<td><strong>Self study:</strong></td>
<td>12h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Learning time: 18h 40m</th>
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</thead>
<tbody>
<tr>
<td><strong>Local algebra</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Regular sequences. Depth. Homological characterizations. Regular rings, Gorenstein rings, Cohen-Macaulay rings</td>
</tr>
<tr>
<td><strong>Learning time:</strong></td>
<td>18h 40m</td>
</tr>
<tr>
<td><strong>Theory classes:</strong></td>
<td>9h</td>
</tr>
<tr>
<td><strong>Self study:</strong></td>
<td>9h 40m</td>
</tr>
</tbody>
</table>
Qualification system

The qualification will be based on:
Active participation of the student during the course,
Resolution of assigned exercises
Exposition of a directed work in which the student develops some material related to the course.
If necessary, a final exam

Bibliography

Basic:
34952 - AG - Algebraic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

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

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

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

Requirements
Basic abstract Algebra, Topology and Differential Geometry.

Degree competences to which the subject contributes

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

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
The main objective of the course is to introduce the student to the Algebraic Geometry of affine and projective varieties, both algebraically over a field (Q, finite fields) and analytically over the real, and specially over the complex numbers. The course will be based on many examples, stressing the geometric interest of the subject. The topic of the final lectures will depend on the interests of the audience, with a view towards the assigned final projects of the students.

**Teaching methodology**

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

**Learning objectives of the subject**

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

**Study load**

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

### Chapter 1: Algebraic equations

**Learning time:** 15h  
- Theory classes: 6h  
- Self study: 9h

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

### Chapter 2: Algebraic varieties

**Learning time:** 13h  
- Theory classes: 6h  
- Self study: 7h

**Description:**  

### Chapter 3: Projective varieties

**Learning time:** 9h  
- Theory classes: 4h  
- Self study: 5h

### Chapter 4: Maps and morphisms

**Learning time:** 13h  
- Theory classes: 6h  
- Self study: 7h

**Description:**  

### Chapter 5: Complex analytic varieties

**Learning time:** 14h  
- Theory classes: 8h  
- Self study: 6h

**Description:**  
Tangent spaces. Nonsingular points. Smooth maps. Global topology of varieties: fundamental class, degree of morphisms, intersection numbers. Applications: determinantal varieties, Grassmanians, parametrizing varieties...
Qualification system

Students who solve enough problems on the blackboard in the problem class pass the course. If they want to improve their grade from pass towards top score they will be assigned a final project, which will be to study and lecture on an additional topic at the end of the course. Students who have not participated enough in the problem class, or still want to improve on their grade after problem class and additional lecture, will have to take a final exam of approximately 4 hours.

Regulations for carrying out activities

The problem list for participation in problem class will be published at the start of every course unit. Students will prepare these problems at home. The topics for optional, grade increasing lectures at the end of the course will be proposed around Easter. Students will prepare these lectures at home. Students who take the final exam will have to do so without any notes, books or material whatsoever.
34952 - AG - Algebraic Geometry

Bibliography

**Basic:**

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

**Complementary:**

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

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

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

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

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

Degree competences to which the subject contributes

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

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

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

Learning objectives of the subject

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

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

Study load

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

Content

**Algebraic Number Theory**

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

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

Qualification system

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

Regulations for carrying out activities

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

Bibliography

Basic:


Others resources:

Computer material

SAGE

Mathematical Software
34954 - CC - Codes and Cryptography

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

Teaching staff

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

Prior skills

Basic probability, basic number theory and linear algebra

Requirements

Undergraduate mathematics

Degree competences to which the subject contributes

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

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

<table>
<thead>
<tr>
<th>Study load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time</strong>: 187h 30m</td>
</tr>
<tr>
<td>Hours large group:</td>
</tr>
<tr>
<td>Self study:</td>
</tr>
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</table>
# 34954 - CC - Codes and Cryptography

## Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 6h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study : 4h 15m</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Section</th>
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<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study : 8h 30m</td>
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<tr>
<td><strong>Source codes without memory</strong></td>
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**Description:**

<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
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<tr>
<td></td>
<td>Self study : 12h 45m</td>
</tr>
<tr>
<td><strong>Channel coding</strong></td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Self study : 12h 45m</td>
</tr>
<tr>
<td><strong>Block codes</strong></td>
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</table>

**Description:**
### Cyclic codes

**Description:**

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

---

### Introduction to modern cryptography

**Description:**

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

---

### Symmetric key cryptography

**Description:**

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

---

### Public key encryption

**Description:**

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

---

### Digital signatures

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

**Learning time:** 15h 38m  
Theory classes: 5h  
Self study: 10h 38m
### Proofs of knowledge and other cryptographic protocols

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

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

### Multiparty computation

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

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

### Qualification system

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

### Regulations for carrying out activities

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

**Basic:**


**Complementary:**


34955 - COMB - Combinatorics

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

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

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

Degree competences to which the subject contributes

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

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

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

Learning objectives of the subject
To use algebraic, probabilistic and analytic methods for studying combinatorial structures. The main topics of study are:
34955 - COMB - Combinatorics

partially ordered sets, extremal set theory, finite geometries, matroids, Ramsey theory and enumerative combinatorics.

Study load

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

**Learning time:** 24h 40m  
Practical classes: 4h  
Laboratory classes: 4h  
Self study: 16h 40m

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

### Extremal set theory

**Learning time:** 24h 40m  
Theory classes: 4h  
Laboratory classes: 4h  
Self study: 16h 40m

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

### Linear algebra methods in combinatorics

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

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

### Finite geometries

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

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

## Matroids

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

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

## Probabilistic methods in combinatorics

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

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

## Ramsey theory

<table>
<thead>
<tr>
<th><strong>Learning time:</strong> 31h 40m</th>
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</thead>
<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Laboratory classes: 5h</td>
</tr>
<tr>
<td>Self study: 21h 40m</td>
</tr>
</tbody>
</table>

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

## Enumerative combinatorics

<table>
<thead>
<tr>
<th><strong>Learning time:</strong> 32h 30m</th>
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<tbody>
<tr>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td>Laboratory classes: 5h</td>
</tr>
<tr>
<td>Self study: 22h 30m</td>
</tr>
</tbody>
</table>

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

## Qualification system

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


34956 - DG - Discrete and Algorithmic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: VERA SACRISTAN ADINOLFI
Others: JULIAN THORALF PFEIFLE - A
VERA SACRISTAN ADINOLFI - A
RODRIGO IGNACIO SILVEIRA - A

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

Degree competences to which the subject contributes

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

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

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

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

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td>187 hours 30 minutes</td>
<td>60h</td>
<td>127 hours 30 minutes</td>
</tr>
<tr>
<td></td>
<td>32.00%</td>
<td>68.00%</td>
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</tbody>
</table>
# 34956 - DG - Discrete and Algorithmic Geometry

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

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

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 19h</th>
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</table>
| Convexity | Theory classes: 4h  
Laboratory classes: 2h  
Self study : 13h |

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

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 31h</th>
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</table>
| Decompositions and arrangements | Theory classes: 7h  
Laboratory classes: 3h  
Self study : 21h |

**Description:**  

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 31h</th>
</tr>
</thead>
</table>
| Proximity Structures | Theory classes: 7h  
Laboratory classes: 3h  
Self study : 21h |

**Description:**  
Proximity problems. Voronoi diagram, Delaunay triangulation. Shape reconstruction.
### Polytopes and Subdivisions of Point Sets

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

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

### Lattice Geometry

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

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

### Symmetry

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

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

### Software

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

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

**Qualification system**

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

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

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

Basic:


Complementary:


Others resources:

Audiovisual material


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

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

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: English

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

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

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

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

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

Learning objectives of the subject
34957 - GT - Graph Theory

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

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

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

| **Symmetries in graphs**               | **Learning time:** 1h  
Theory classes: 1h |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
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| **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:** |                  |
**34957 - GT - Graph Theory**

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

**Qualification system**

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

**Regulations for carrying out activities**

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

**Bibliography**

**Basic:**

34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff
Coordinator: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ
Others: XAVIER CABRE VILAGUT - A
FERNANDO CHARRO CABALLERO - A
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 INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
The course will provide a general overview on the use of partial differential equations (PDE) and boundary value problems to construct mathematical models of real phenomena. By the end of the course the student should have acquired:

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

**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**

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>127h 30m</td>
<td>Self study:</td>
<td>68.00%</td>
</tr>
<tr>
<td>Content</td>
<td>Learning time: 56h 15m</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------------</td>
<td></td>
</tr>
<tr>
<td>1 Heat conduction and diffusion</td>
<td>Theory classes: 18h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self study: 38h 15m</td>
<td></td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 56h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Potentials in physics and technology</td>
<td>Theory classes: 18h</td>
</tr>
<tr>
<td></td>
<td>Self study: 38h 15m</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 31h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Transients in continuous media</td>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td></td>
<td>Self study: 21h 15m</td>
</tr>
</tbody>
</table>

**Description:**
Acoustics, surface gravity waves, inertial waves. Electromagnetic and elastic waves. Dispersion, Stationary waves and high-frequency waves.

<table>
<thead>
<tr>
<th>Content</th>
<th>Learning time: 23h 26m</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Geometry</td>
<td>Theory classes: 7h 30m</td>
</tr>
<tr>
<td></td>
<td>Self study: 15h 56m</td>
</tr>
</tbody>
</table>

**Description:**
The Laplace-Beltrami operator. Minimal surfaces.
### 5 Games and optimization

<table>
<thead>
<tr>
<th><strong>Description:</strong></th>
<th><strong>Learning time:</strong> 23h 26m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random games.</td>
<td>Theory classes: 7h 30m</td>
</tr>
<tr>
<td>Optimal transport.</td>
<td>Self study: 15h 56m</td>
</tr>
</tbody>
</table>

### Qualification system

Attendance to lectures, presentation of additional materials and problem solving will be the basis of a qualification up to a certain level (60%). A higher mark will require a written exam.

### Bibliography

#### Basic:


#### Complementary:

34959 - CM - Computational Mechanics

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

Teaching staff
Coordinator: JOSE JAVIER MUÑOZ ROMERO
Others: JOSE JAVIER MUÑOZ ROMERO - A

Prior skills
Basic knowledge of numerical methods
Basic knowledge of partial differential equations

Degree competences to which the subject contributes

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

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

Four elements will be combined:
- Theory classes, where the main concepts will be presented.
- Practical classes with Matlab code in the computer room, with emphasis on the computational aspects.
- Lists of short assignments.
- Course projects, with applications in biomechanics. To be presented at the end of the course.

Students will work on the assignments and course projects individually or in groups.

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. Some emphasis is put on applications in biomechanical problems. By the end of the course, the students should:
- Be able to choose the appropriate type of model for a specific simulation
- Be familiar with the mathematical objects (mainly tensors) used in computational mechanics
- Be aware of the different level of complexity of various problems (e.g. linear vs. nonlinear, static vs. dynamic).

Study load

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

<table>
<thead>
<tr>
<th><strong>CONTINUUM MECHANICS</strong></th>
<th><strong>Learning time:</strong> 31h 15m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 21h 15m</td>
</tr>
</tbody>
</table>


### COMPUTATIONAL ELASTICITY

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


### COMPUTATIONAL DYNAMICS

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

### COMPUTATIONAL PLASTICITY

**Learning time:** 31h 15m  
**Description:**  

### COMPUTATIONAL FLUID DYNAMICS

**Learning time:** 31h 15m  
**Description:**  

### COMPUTATIONAL METHODS FOR WAVE PROBLEMS

**Learning time:** 31h 15m  
**Description:**  
Basic concepts and motivation.  

### Qualification system

Final exam, assigned problems, and course project.
Bibliography

Basic:


Complementary:


34960 - MMB - Mathematical Models in Biology

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5

Teaching languages: English

Teaching staff

Coordinator: JESUS FERNANDEZ SANCHEZ
Others:
- MARTA CASANELLAS RIUS - A
- JESUS FERNANDEZ SANCHEZ - A
- GEMMA HUGUET CASADES - A
- JOAQUIM PUIG SADURNI - A

Prior skills

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

Requirements

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

Degree competences to which the subject contributes

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

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

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

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

Teaching methodology

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

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

Learning objectives of the subject

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

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

## Mathematical models in Genomics

**Learning time:** 75h  
Theory classes: 12h  
Laboratory classes: 12h  
Self study: 51h

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

## Mathematical Models in Neurophysiology

**Learning time:** 56h 15m  
Theory classes: 9h  
Laboratory classes: 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.

## Models of Population Dynamics

**Learning time:** 37h 30m  
Theory classes: 6h  
Laboratory classes: 6h  
Self study: 25h 30m

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

**Biological networks**

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

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

**Qualification system**

50%: Each of the five blocks will give a part (10%) of the qualification, based on the performance on the short-projects.
20%: Overall evaluation of the participation, interest and proficiency evinced along the course.
30%: Final exam aiming at validating the acquisition of the most basic concepts of each block.
34960 - MMB - Mathematical Models in Biology

Bibliography

Basic:


Complementary:


34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: AMADEU DELSHAMS I VALDES
Others: AMADEU DELSHAMS I VALDES - A
PABLO MARTIN DE LA TORRE - A

Opening hours

Timetable: Make an appointment by email

Prior skills

Good knowledge of calculus, algebra and differential equations. It is strongly recommended a good understanding of the basic theory of ordinary differential equations as well as a basic knowledge of dynamical systems from a local point of view.

Degree competences to which the subject contributes

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

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
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9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Teaching methodology

We do not 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

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Invariant objects in Dynamical Systems</strong></td>
<td>Other activities: 10h</td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Continuous and discrete Dynamical Systems.</td>
<td></td>
</tr>
<tr>
<td>Poincaré map.</td>
<td></td>
</tr>
<tr>
<td>Local behaviour of hyperbolic invariant objects.</td>
<td></td>
</tr>
<tr>
<td>Invariant manifolds. Central manifold.</td>
<td></td>
</tr>
<tr>
<td>Local bifurcations.</td>
<td></td>
</tr>
</tbody>
</table>

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

| **Variational Aspects of Dynamics**                                  | Other activities: 10h |
| **Description:**                                                     |                    |
| Critical points of functions, Morse theory, and dynamics.            |                    |
| The billiard problem.                                                |                    |
| Twist maps.                                                          |                    |
| Variational description of Lagrangian systems.                       |                    |
| Local theory and the exponential map.                                |                    |
| Minimal geodesics.                                                   |                    |
| Minimal geodesics on compact surfaces.                               |                    |

| **Homoclinic points and chaotic Dynamics**                           | Other activities: 10h |
| **Description:**                                                     |                    |
| Smale horseshoe.                                                     |                    |
| Homoclinic points and bifurcations.                                  |                    |
| Hyperbolic sets and transversal homoclinic points.                  |                    |
| Dynamical systems with chaotic dynamics.                             |                    |
| Newhouse phenomenon.                                                |                    |
The students have to do some problems and a research work. On the other hand they will attend the winter courses "Recent trends in non-linear science" and produce a document about them.

Qualification system

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

Regulations for carrying out activities

There will be a final exam covering the theoretical part of the course.

Bibliography

Basic:


34962 - HS - Hamiltonian Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

Teaching staff

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

Prior skills

Knowledge of calculus, algebra and ordinary differential equations.

Degree competences to which the subject contributes

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

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

Teaching methodology

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

**Learning objectives of the subject**

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

**Study load**

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

<table>
<thead>
<tr>
<th><strong>Hamiltonian formalism</strong></th>
<th><strong>Learning time:</strong> 28h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td></td>
<td>Self study : 18h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th><strong>Hamiltonian and Lagrangian systems</strong></th>
<th><strong>Learning time:</strong> 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
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<tr>
<td></td>
<td>Self study : 8h</td>
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**Description:**

<table>
<thead>
<tr>
<th><strong>Integrable and quasi-integrable Hamiltonian systems</strong></th>
<th><strong>Learning time:</strong> 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study : 8h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th><strong>Invariant objects of Hamiltonian systems</strong></th>
<th><strong>Learning time:</strong> 24h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td></td>
<td>Self study : 16h</td>
</tr>
</tbody>
</table>

**Description:**
Continuous and discrete dynamical systems, Poincaré map. Local structure of hyperbolic invariant objects: invariant manifolds. Center manifold. Lyapunov Center Theorem.
34962 - HS - Hamiltonian Systems

**Stability of dynamical systems and Hamiltonian systems**

**Description:**
Averaging Theory, Lie Series, Small divisors and Diophantine inequalities, KAM theory (Kolmogorov-Arnold-Moser), Effective stability and Nekhoroshev theorem, Splitting of separatrices, Melnikov potential, Arnold diffusion.

**Learning time:** 28h
- Theory classes: 10h
- Self study: 18h

**Applications to celestial mechanics**

**Description:**

**Learning time:** 34h
- Theory classes: 12h
- Self study: 22h

**- Interactions between Dynamical Systems and Partial Differential Equations**

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

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

**Planning of activities**

**JISD summer school**

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

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

**Qualification system**

The students have to do some problems and a project. There will be also an exam of the theoretical part of the course. Moreover, they will attend the JISD and produce a document about them.
34962 - HS - Hamiltonian Systems

Bibliography

Basic:


Others resources:

Hyperlink

Grup de sistemes dinàmics https://recerca.upc.edu/sd

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

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 749 - MAT - Department of Mathematics  
**Academic year:** 2016  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)  
**ECTS credits:** 7,5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** XAVIER CABRE VILAGUT  
**Others:**  
XAVIER CABRE VILAGUT - A  
ALBERT MAS BLESAS - A

### Prior skills

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

### Requirements

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.

### Degree competences to which the subject contributes

**Specific:**

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

**Transversal:**

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

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

Study load

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

| **Classical methods for the Poisson and heat equations** | **Learning time:** 47h  
  - Theory classes: 15h  
  - Self study: 32h |
|--------------------------------------------------------|-------------------------------------------------|
| **Description:**  
  Maximum principles and Green's functions for the Poisson and heat equations. |

| **Sobolev spaces and variational methods** | **Learning time:** 47h  
  - Theory classes: 15h  
  - 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  
  - Theory classes: 15h  
  - Self study: 31h 45m |
|------------------------|-------------------------------------------------|
| **Description:**  

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

### Qualification system

The evaluation of the course is based:
- on the weekly resolution of problems proposed in class (15%);
- a midterm exam (35%);
- a final comprehensive exam (50%).
- eventually, there could be the possibility of a final project in order to improve the grade.
- the active participation during the course will be a requirement for the evaluation of the final exam.
34963 - ACPDE - Advanced Course in Partial Differential Equations

Bibliography

Basic:


Complementary:


34964 - NMDS - Numerical Methods for Dynamical Systems

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

Teaching staff

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

Prior skills

Good knowledge of a programming language.

Requirements

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

Degree competences to which the subject contributes

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

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34964 - NMDS - Numerical Methods for Dynamical Systems

Teaching methodology

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

Learning objectives of the subject

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

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study: 127h 30m 68.00%</td>
</tr>
</tbody>
</table>
34964 - NMDS - Numerical Methods for Dynamical Systems

### Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 4h</th>
<th>Theory classes: 2h</th>
<th>Practical classes: 2h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical (preliminary) tools for practical purposes: integrators for ODE and graphical interfaces. Examples.</td>
<td></td>
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</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 10h</th>
<th>Theory classes: 5h</th>
<th>Practical classes: 5h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation and stability of periodic orbits. Implementation, continuation of families, bifurcations. Multiple shooting.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 15h</th>
<th>Theory classes: 7h 30m</th>
<th>Practical classes: 7h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation of tori: representation, computation and continuation. Implementation and examples.</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 15h</th>
<th>Theory classes: 7h 30m</th>
<th>Practical classes: 7h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis of bifurcations. Some examples.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

**Qualification system**

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

**Regulations for carrying out activities**

No rules, in principle.

**Bibliography**

**Basic:**


Particular articles related to the topics of the course and some notes from suitable web pages.
34965 - NMPDE - Numerical Methods for Partial Differential Equations

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
751 - ECA - Department of Civil and Environmental Engineering

Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5 Teaching languages: English

Teaching staff
Coordinator: PEDRO DIEZ MEJIA
Others:
PEDRO DIEZ MEJIA - A
SONIA FERNANDEZ MENDEZ - A
ABEL GARGALLO PEIRO - A

Prior skills
Basics on numerical methods, differential equations and calculus.

Degree competences to which the subject contributes

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

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

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

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

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

Learning objectives of the subject

Teaching methodology

Lectures, practical work at computer room, exercises and home works.
## Content

<table>
<thead>
<tr>
<th><strong>Fundamentals of Finite Element Methods (FEM)</strong></th>
<th><strong>Learning time:</strong> 20h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 10h</td>
<td>Laboratory classes: 10h</td>
</tr>
</tbody>
</table>

**Description:**
Basic concepts of the Finite Element Method (FEM) for elliptic and parabolic equations: strong and weak form, discretization, implementation, functional analysis tools, error bounds and convergence, time integration for parabolic equations.
Application to the numerical modelling of flow in porous medium, and potential flow.
Introduction to a posteriori error estimation and adaptivity.
Solution of the convection-diffusion equation. Stabilized formulations for convection dominated problems.

<table>
<thead>
<tr>
<th><strong>FEM for incompressible flow problems</strong></th>
<th><strong>Learning time:</strong> 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
<td>Practical classes: 2h</td>
</tr>
</tbody>
</table>

**Description:**
Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition.
Application to microfluidics and geophysics.
Introduction to the numerical solution of the incompressible Navier-Stokes equations.
Introduction to eXtended FEM (X-FEM) for two-phase problems.

<table>
<thead>
<tr>
<th><strong>FEM for wave problems</strong></th>
<th><strong>Learning time:</strong> 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
<td>Laboratory classes: 6h</td>
</tr>
</tbody>
</table>

**Description:**
FEM solution of the 1D wave equation. FEM solution of Helmholtz equation. Non-reflecting boundary conditions.
Application to acoustics.
Introduction to DG for first order conservation laws. Application to acoustics and electromagnetics.
34965 - NMPDE - Numerical Methods for Partial Differential Equations

**Stochastic FEM**

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

**Description:**

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

**Bibliography**

**Basic:**


**Complementary:**

34966 - VD - Differentiable Manifolds

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2016
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7.5  
Teaching languages: English

Teaching staff

Coordinator: MIGUEL ANDRES RODRIGUEZ OLMOS
Others: EVA MIRANDA GALCERÁN - A  
MIGUEL ANDRES RODRIGUEZ OLMOS - A

Prior skills

Basic courses on algebra, calculus, topology and differential equations, and calculus on manifolds. Students from the FME are supposed to have taken "Varietats Diferenciables" (optional 4th year course).

This is not a basic course and the students are assumed to have attended previous courses on differential geometry and smooth manifolds. Students feeling that they may not fulfill the requisites are invited to discuss their case with the lecturers. It is totally possible for prospective students with a lesser knowledge in these topics to follow this course provided they are willing to make up for the gap with individual work during the course and/or by reading some recommended bibliography prior to the beginning of the course.

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.
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9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
The subject focuses on some of the fundamental topics of differential geometry and its applications in different areas, as geometric mechanics, control theory, classic and quantum field theory, fluid mechanics, computer vision, geophysical dynamics, general relativity and more.

By the end of the course, students should be able to:
- understand all the ideas developed along the course.
- apply the studied concepts to other areas of pure mathematics, physics and engineering.
- integrate in a research group on these kinds of topics and their applications.
- search and understand the scientific literature on the subject.
- write and present an essay on mathematics.

| Study load | Total learning time: 187h 30m | Hours large group: 60h 32.00% | Self study: 127h 30m 68.00% |
### Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reminder of Manifold Theory and Exterior Calculus</strong></td>
<td><strong>12h 52m</strong></td>
<td><strong>Description:</strong> Brief survey of manifold theory and differential geometry. Manifolds, atlases, smooth maps, tangent vectors and vector fields, flows, exterior calculus.</td>
</tr>
<tr>
<td><strong>De Rham Cohomology and Integration Theory</strong></td>
<td><strong>25h</strong></td>
<td><strong>Description:</strong> We define De Rham cohomology and compare to other cohomologies. We will also introduce De Rham computation kit and Poincaré duality.</td>
</tr>
<tr>
<td><strong>Symplectic and Poisson Geometry</strong></td>
<td><strong>43h 45m</strong></td>
<td><strong>Description:</strong> Introduction to symplectic and Poisson manifolds with emphasis on examples. Starting with symplectic manifolds, we will explain Moser's trick and some applications to normal form theorems such as the Darboux theorem or the Lagrangian neighbourhood theorem. Special attention will be given to examples provided by the realm of integrable systems. We end the chapter introducing the basic concepts in Poisson geometry.</td>
</tr>
<tr>
<td><strong>Lie groups and Lie algebras. Actions on Manifolds</strong></td>
<td><strong>25h</strong></td>
<td><strong>Description:</strong> Introduction to the main aspects of the theory of Lie groups and their actions on manifolds, including classic groups, subgroups, actions, orbits and quotients.</td>
</tr>
</tbody>
</table>
### Principal Bundles

**Learning time:** 18h 45m  
**Description:**  
The concept of fibre bundes and local triviality will be introduced. Then we define the main object of study, principal bundles and their main example, frame bundles, as well as their properties.

### Connections and Curvature

**Learning time:** 18h 45m  
**Description:**  
We introduce connections on principal bundles and study their existence and main constructions and properties, as curvature, holonomy, parallelism and structure equations.

### Vector Bundles and Associated Bundles

**Learning time:** 18h 45m  
**Description:**  
We will study constructions in bundle theory, as associated and pullback bundles, and the theory of general vector bundles. The main objective is to introduce connections on vector bundles and their properties, as well as their relationship with connections on principal bundles.

### Qualification system

There will be a final exam, as well as the possibility to write an optional essay that would contribute to the final grade. Students would choose, together with the lecturers, a topic that complements or advances the material taught during the course, according to their mathematical interests.

### Regulations for carrying out activities

The final grade awarded to the student would we computed as follows:

- **Case A:** an student that does only the final exam. Then the final grade would be that of the exam.
- **Case B:** an student that does the final exam AND submits a written essay. Then the final note would be the result of $\text{MAX}(\text{exam, 60\% exam + 40\% essay})$
Bibliography

Basic:


Complementary: