Guia Docent

18/19

Facultat de Matemàtiques i Estadística

Master in Advanced Mathematics Mathematical Engineering

Sofia Kovalevskaya
15/01/1850 – 10/02/1891

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Facultat de Matemàtiques i Estadística
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# Master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)

The master's degree in Advanced Mathematics and Mathematical Engineering (MAMME) is a master’s programme in mathematics offered at the 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 teamwork, in collaboration with engineers, physicists, biologists, economists, etc).

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

## GENERAL DETAILS

<table>
<thead>
<tr>
<th><strong>Duration and start date</strong></th>
<th>One academic year, 60 ECTS credits. Starting September and February</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timetable and delivery</strong></td>
<td>Afternoons. Face-to-face</td>
</tr>
<tr>
<td><strong>Fees and grants</strong></td>
<td>Approximate fees for the master's degree, excluding degree certificate fee, €3,267 (€4,900 for non-EU residents).</td>
</tr>
<tr>
<td></td>
<td><a href="#">More information about fees and payment options</a></td>
</tr>
<tr>
<td></td>
<td><a href="#">More information about grants and loans</a></td>
</tr>
<tr>
<td><strong>Language of instruction</strong></td>
<td>English</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>School of Mathematics and Statistics (FME)</td>
</tr>
<tr>
<td><strong>Official degree</strong></td>
<td>Recorded in the Ministry of Education's degree register</td>
</tr>
</tbody>
</table>

## ADMISSION

### General requirements

Academic requirements for admission to master's degrees

### Specific requirements

This master's degree is aimed at students with good abstract reasoning, an 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's degree 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: the academic record, the CV, a statement of purpose and, if deemed necessary, a personal interview and recommendation letters.

Places
30

Pre-enrolment
Pre-enrolment closed (consult the new pre-enrolment periods in the academic calendar).

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.

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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.)

PROFESSIONAL OPPORTUNITIES

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 and applied research (biomedical research centres, 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
On completing this master's degree, students will be able to

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.
ORGANISATION

UPC school  
School of Mathematics and Statistics (FME)

Academic coordinator  
Sonia Fernández Méndez

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

CURRICULUM

<table>
<thead>
<tr>
<th>Subjects</th>
<th>ECTS credits</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRST SEMESTER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Codes and Cryptography</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Commutative Algebra</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Graph Theory</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Mathematical Modelling with Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Mathematical Models in Biology</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Non-Commutative Algebra</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Number Theory</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Numerical Methods for Dynamical Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Numerical Methods for Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Quantitative and Qualitative Methods in Dynamical Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td><strong>SECOND SEMESTER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Course in Partial Differential Equations</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Algebraic Geometry</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Combinatorics</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Differentiable Manifolds</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Hamiltonian Systems</td>
<td>7.5</td>
<td>Optional</td>
</tr>
</tbody>
</table>

November 2018. UPC. Universitat Politècnica de Catalunya · BarcelonaTech
Study program and MAMME Courses

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).

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 (Autumn term Q1) [not for academic year 2018-2019]
- Algebraic Geometry (Spring term Q2) [not for academic year 2019-2020]
- Differentiable Manifolds (Spring term Q2) [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 (Autumn term Q1)

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 Projectos.

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.
Focus on Discrete Mathematics

Discrete Mathematics has had a strong development from the second half of the XXth century fostered by the development of computers and communication technologies. The main topics include algorithms, coding theory, combinatorics, cryptography, discrete and computational geometry, finite geometry, game theory, graph theory, logic, operation research and random structures. Besides the wealth of problems which have become central in the development of contemporary mathematics, discrete mathematics holds a strong connection with applications in Bioinformatics, Computer Graphics, Information Theory, Networks or Theoretical Computer Science, as well as with other areas of mathematics like Algebra, Analysis, Number Theory or Topology.

The UPC gathers one of the strongest research groups in Spain in the area with a broad international projection providing a sound training. Most of the former students of the master have found job opportunities in industry and in academics by pursuing a PhD in UPC or in prestigious universities in Europe, the USA or Canada.

Random graphs, the basic model for random structures

Triangulations, a basic tool for computational geometry

Cryptography, one of the key applications of discrete mathematics

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Students interested in focusing on Discrete Mathematics are invited to select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combinatorics</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Graph Theory</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Codes an Cryptography</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Optimizacion Entera y Combinatoria</td>
<td>5</td>
<td>Spanish</td>
<td>Máster Univ. en Estadística e Investigación Operativa, UPC-UB</td>
</tr>
<tr>
<td>Algorithmic Methods for Mathematical Models</td>
<td>6</td>
<td>English</td>
<td>Master in Innovation and Research in Informatics, UPC</td>
</tr>
<tr>
<td>Computational Complexity</td>
<td>6</td>
<td>English</td>
<td>Master in Innovation and Research in Informatics, UPC</td>
</tr>
<tr>
<td>Combinatorial Set Theory</td>
<td>6</td>
<td>English</td>
<td>Master in Pure and Applied Logic, UB-UPC</td>
</tr>
</tbody>
</table>

Registration to non-MAMME courses requires the approval of the director of the corresponding master program.

Recall that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.
Focus on Partial Differential Equations and Analysis

Partial Differential Equations (PDEs) play a central role in physics, chemistry, biology, industry, mathematical finance, and image processing. Their analysis often requires deep mathematical techniques, which makes PDEs at the heart of both historical and recent developments in analysis, geometry, and probability. Because of this and their applications, PDEs is a very active area of mathematics, the one with the largest number of publications.

Pattern formation with reaction-diffusion systems of PDEs

Free boundaries and PDEs: the Stefan problem for melting ice

Lévy flights and PDEs in finance, biological invasions...

Students interested in focusing on PDEs and Analysis are invited to select 45 ECTS from this list and the suggestions below:

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced course in PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical Modeling with PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Stochastic Calculus</td>
<td>7.5</td>
<td>English</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Complex Analysis</td>
<td>9</td>
<td>English</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

A minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

Other appropriate courses (depending on the student interests) with connections to PDEs are: Quantitative and Qualitative Methods in Dynamical Systems (Q1 MAMME), Hamiltonian Systems (Q2 MAMME), and courses within the Barcelona universities masters offer in Mathematical Finance, Mathematical Biology, Image Processing, Functional Analysis, or Differential Geometry.
Focus on Mathematical and Computational Modelling with PDEs

Mathematical and computational modelling with Partial Differential Equations (PDEs) is nowadays an essential tool for analysing, understanding and predicting phenomena in physics, biology, engineering, economics, social sciences and related fields. The applications cover a wide spectrum ranging from the modelling of the aerodynamical behaviour of an airfoil, to the simulation of the impact of a tsunami in a coastal area, or the study of fracture in epithelial cell sheets.

Students interested in focusing on modelling with PDEs are invited to select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical Modelling with PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced Course in PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced Fluid Mechanics**</td>
<td>5</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Finite Elements in Fluids**</td>
<td>5</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Advanced Discretization Methods**</td>
<td>5</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Numerical Modelling*</td>
<td>9</td>
<td>English</td>
<td>Master en Enginyeria de Camins, Canals i Ports, UPC</td>
</tr>
</tbody>
</table>

Recall that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

(*) “Numerical Modeling” is recommended to students that do not have a solid background in numerical methods and programming. Registration to this course requires the approval of the director of the corresponding master.

(**) These courses are proposed to students willing to get a deeper focus on numerical methods for PDEs and their applications.
Focus on Optimization and Operation Research for Efficient Decision Making

Efficient decision making based on quantitative results is essential for success in business and management. Operations Research (also known as “Management Sciences” or “Analytics”) is a discipline that deals with the application of advanced analytical methods to help make better decisions. Project planning, network optimization, facility location, routing, supply chain management, scheduling, among others, are real problems tackled by Operation Research. Industrial sectors that benefit from Operation Research range from airlines (scheduling, tariff policy), to hospitals (scheduling), to electric utilities (production, trading) and logistics (route scheduling).

Travelling salesman problem solution

Traffic simulation system

Students interested in focusing on Optimization and Operation Research should select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Optimization</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Optimization in Energy Systems and Markets</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Stochastic Optimization</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Large Scale Optimization</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Integer and Combinatorial Optimization*</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Statistical Data Protection*</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Graph Theory*</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Combinatorics*</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical Models in Biology</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for Dynamical Systems</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for Partial Differential Equations</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
</tbody>
</table>

Recall that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

(*) These courses are proposed to students willing to get a deeper focus on discrete and combinatorial optimization.
Focus on Modelling and Analysis in Biomedical Sciences

Research in biomedical sciences increasingly involves mathematical modelling as a support to validate theories, to test computational replicas, to manage biomedical data and to deal with new challenges that are hard to explore either clinically or experimentally. All these goals require scientists with the solid basis provided in standard mathematical undergraduate programs, but also equipped with advanced mathematical and computational tools, as well as a practical spirit, to serve at the interface of biology, medicine, mathematics and computation. Fortunately, while the MAMME program gives the opportunity of acquiring a basic knowledge of mathematical models in biology and advanced mathematical/computational tools, other master’s programs at UPC, allow offering a complete training to prepare our students in this stimulating interdisciplinary area. Students interested in joining this area through the MAMME will receive advice from the master’s coordination to tailor their curriculum according to different scopes in mathematical modelling of biomedical sciences. We aim at giving a broad training in the mathematical modelling of medically significant biological problems and, additionally, endow their careers with an initial subfocus in some specific problems. The list of courses below represent the wide offer at the UPC to tailor specific profiles (the student has to select 45 ECTS from it), which can be also complemented with problem-oriented master’s theses (for example, study of phylogenetic trees, mathematical and computational neuroscience, electro-mechanical models in cardiac physiology, mathematical epidemiology,...), eventually co-advised with partners in biomedical labs. Researchers involved in the area offer their advice to adapt the curriculum to each student’s background and interests.

Brain dynamics: modelling and analysis at different levels, with different tools (differential equations, graphs, statistics,...)

Simulation of curved cellular monolayers with computational mechanics
<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical models in biology</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for dynamical systems</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical Modeling with PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Qualitative and quantitative methods in dynamical systems</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Graph theory</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Inferencia estadística avanzada</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Fundamentos de bioinformatica</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Multivariate data analysis</td>
<td>5</td>
<td>Spanish-English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Probability and stochastic processes</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Time series</td>
<td>5</td>
<td>Spanish-English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Numerical Modeling*</td>
<td>9</td>
<td>English</td>
<td>Máster en Enginyeria de Camins, Canals i Ports, UPC</td>
</tr>
<tr>
<td>Técnicas básicas en neurociencia**</td>
<td>5</td>
<td>ECTS</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Biología Celular y Molecular de la Neurona**</td>
<td>5</td>
<td>ECTS</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Diseño y análisis de datos en neurociencia cognitiva**</td>
<td>2.5</td>
<td>ECTS</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Neurociencia computacional**</td>
<td>2.5</td>
<td>ECTS</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
</tbody>
</table>

We remind that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

(*) "Numerical Modeling" is recommended to students that do not have a solid background in numerical methods and programming. Registration to this course requires the approval of the director of the corresponding master.

(**) These courses are proposed to students willing to get a deeper focus neuroscience. Registration to these courses requires the approval of the director of the corresponding master.
Focus on Algebra, Geometry and Number Theory

Mathematics departments at UPC gather several research groups specialized in Number Theory, Algebraic Geometry, Differential Geometry and commutative and non-commutative Algebra. All of them collaborate closely with other researchers of the Universitat de Barcelona and the Universitat Autònoma de Barcelona, and with research groups of some of the most prestigious universities around the world. Many young researchers began their scientific careers by coursing the Master and/or doing the PhD in one of the UPC groups: Ariadna, Biel, Carlos, Enrique, Francesc, Francesc, Marc, Maria, Martí, Pere-Daniel, Santi, Victor, Xavi, among others.

A knowledge of some basics in Algebra, Geometry and Number Theory is also very useful for people aimed to work in applications of Mathematics to Cryptography, Coding Theory, Discrete Mathematics, Control Theory, Mathematical Physics, Algorithmics, Biosciences, etc.

Students interested in focusing on Algebra, Geometry and Number Theory are invited to select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commutative Algebra*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Non-Commutative Algebra*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Differentiable Manifolds*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Number Theory*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Algebraic Geometry*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Geometry and Topology of Varieties</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Algebraic Curves**</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Computational Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Geometrical Methods in Number Theory</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Local Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

A minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

(*) Please check at the Study Program web page if this course is offered in the academic year you are interested in.

(**) This course is not recommended to students who have followed the course “Geometría Algebraica” of Grau en Matemàtiques at FME.
Focus on Dynamical Systems and Applications to Celestial Mechanics

Dynamical Systems provide a powerful mathematical background to explore a great variety of models involving natural and social sciences, physics, chemistry, ecology, economics, neuroscience, astrodynamics among other fields. As a consequence Dynamical Systems theory has become an important and attractive branch of mathematics to students in many disciplines.

The courses proposed below aim at acquiring a basic and transversal knowledge of both the theory of Dynamical Systems as well as computational tools. Along the courses several applications are considered (see the course on ‘Mathematical methods in Biology’) but special emphasis is focused on Celestial Mechanics.

Other complementary courses from the Master at the Universitat de Barcelona are also given.

<table>
<thead>
<tr>
<th>Qualitative and quantitative methods in dynamical systems</th>
<th>7.5 ECTS</th>
<th>English</th>
<th>MAMME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical methods for dynamical systems</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Hamiltonian systems</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical models in biology</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced course in partial differential equations</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Astrodynamics</td>
<td>5 ECTS</td>
<td>English</td>
<td>Master’s degree in Aerospace Science and Technology (UPC)</td>
</tr>
<tr>
<td>Dynamical systems</td>
<td>6 ECTS</td>
<td>English</td>
<td>Master’s degree in advanced and professional mathematics (UB)</td>
</tr>
<tr>
<td>Simulation methods</td>
<td>5 ECTS</td>
<td>English</td>
<td>Master’s degree in advanced and professional mathematics (UB)</td>
</tr>
</tbody>
</table>
Focus on Geometry and its applications

Geometry is a multifaceted research field which is at the crossroad of other topics such as Mathematical Physics and Applied Mathematics. The different branches of Geometry include Algebraic Geometry and its applications to Phylogenetics and Robotics, Algebraic Topology and its applications to Computational Topology, Differential Geometry and its applications to Mathematical Physics and Control Theory.

Students interested in focusing on Geometry and its applications are invited to select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commutative Algebra</td>
<td>MAMME</td>
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<tr>
<td>Differentiable Manifolds</td>
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</tbody>
</table>

A minimum of 3 MAMME courses (22.5 ECTS) is mandatory.
Master's degree in Advanced Mathematics and Mathematical Engineering

2018-2019

34951  NON-COMMUTATIVE ALGEBRA
34952  ALGEBRAIC GEOMETRY
34953  NUMBER THEORY
34954  CODES AND CRYPTOGRAPHY
34955  COMBINATORICS
34956  DISCRETE AND ALGORITHMIC GEOMETRY
34957  GRAPH THEORY
34958  MATHEMATICAL MODELLING WITH PARTIAL DIFFERENTIAL EQUATIONS
34959  COMPUTATIONAL MECHANICS
34960  MATHEMATICAL MODELS IN BIOLOGY
34961  QUANTITATIVE AND QUALITATIVE METHODS IN DYNAMICAL SYSTEMS
34962  HAMILTONIAN SYSTEMS
34963  ADVANCED COURSE IN PARTIAL DIFFERENTIAL EQUATIONS
34964  NUMERICAL METHODS FOR DYNAMICAL SYSTEMS
34965  NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
34966  DIFFERENTIABLE MANIFOLDS
34951 - NCA - Non-Commutative Algebra

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
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: ENRIC VENTURA CAPELL
Others: Primer quadrimestre:
        JOSE BURILLO PUIG - A
        ENRIC VENTURA CAPELL - A

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

Requirements
The basic algebra courses from the degree in mathematics.

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

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
Classes follow the traditional structure of lecture by the professor, together with the assignment of problems and exercises for the students to solve and present, either in written or in oral form.
34951 - NCA - Non-Commutative Algebra

**Learning objectives of the subject**

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

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

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

**Study load**

<table>
<thead>
<tr>
<th><strong>Total learning time:</strong> 187h 30m</th>
<th>Hours large group: 60h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self study:</strong> 127h 30m</td>
<td></td>
<td>68.00%</td>
</tr>
</tbody>
</table>
# 34951 - NCA - Non-Commutative Algebra

## Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generalities about infinite groups</strong></td>
<td>47h</td>
</tr>
<tr>
<td>Theory classes: 15h</td>
<td></td>
</tr>
<tr>
<td>Self study: 32h</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>The free group: basic definitions.</td>
<td></td>
</tr>
<tr>
<td>Presentations: generators and relations.</td>
<td></td>
</tr>
<tr>
<td>Short exact sequences, direct and semidirect products.</td>
<td></td>
</tr>
<tr>
<td>Free products, amalgams, HNN extensions.</td>
<td></td>
</tr>
<tr>
<td>Thompson’s group as an example.</td>
<td></td>
</tr>
</tbody>
</table>

| **The classical Dehn problems in group theory**            | 25h           |
| Theory classes: 8h                                        |
| Self study: 17h                                           |
| **Description:**                                          |               |
| Description of the three classical algorithmic problems in |
| group theory: word, conjugacy and isomorphism problems.    |
| Resolution of the word and conjugacy problems in simple    |
| cases: abelian, free, free-like constructions, residually  |
| finite, etc.                                              |
| Examples of algorithmically unsolvable problems: word,    |
| membership, isomorphism problems, $F_2 \times F_2$.       |

| **The free group**                                        | 47h           |
| Theory classes: 15h                                      |
| Self study: 32h                                           |
| **Description:**                                          |               |
| Stallings foldings and the lattice of subgroups of the    |
| free group.                                               |
| Membership, conjugacy, finite index, intersection of      |
| subgroups.                                                |
| Hall’s theorem and residual properties of free groups.    |

| **Cayley graphs**                                         | 31h           |
| Theory classes: 10h                                      |
| Self study: 21h                                           |
| **Description:**                                          |               |
| Cayley graph and the word metric in a group.              |
| Dehn function, examples; characterization of the          |
| solvability of the word problem via Dehn functions.       |
| Growth of a group, examples. Gromov theorem.              |
The student will have to develop a subject, first in term paper form, of about 15-20 pages, and also as a one to two hours lecture. The subject can be assigned by the teacher, or it can be picked by the student, among all topics in Geometric Group Theory of his interest.

**Qualification system**

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

**Bibliography**

**Basic:**


**Complementary:**


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**Hyperbolic groups**

**Learning time:** 37h 30m

- Theory classes: 12h
- Self study: 25h 30m

**Description:**

Definition of hyperbolic groups.
First properties, finite generation, centralizers.
Characterization of hyperbolic groups as those having linear Dehn function.
34952 - AG - Algebraic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
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: Segon quadrimestre: 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.
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7. 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.
34952 - AG - Algebraic Geometry

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: 60h</th>
<th>32.00%</th>
</tr>
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<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Algebraic equations</th>
<th>Learning time: 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study: 9h</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Algebraic varieties</th>
<th>Learning time: 13h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study: 7h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Projective varieties</th>
<th>Learning time: 9h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study: 5h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Maps and morphisms</th>
<th>Learning time: 13h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study: 7h</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Complex analytic varieties</th>
<th>Learning time: 14h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self study: 6h</td>
</tr>
</tbody>
</table>

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

**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.
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: 2018
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: ANA RIO DOVAL
Others: Primer quadrimestre:
JORDI GUARDIA RUBIES - A
JOAN CARLES LARIO LOYO - A
ANA RIO DOVAL - A

Prior skills

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

Requirements

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

Degree competences to which the subject contributes

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

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
34953 - NT - Number Theory

Teaching methodology

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

Learning objectives of the subject

1) Algebraic number theory.
2) Arithmetic of elliptic and hyperelliptic curves
3) Applications

The material covered in this course interplays with topics of applied arithmetic and number theory (primality testing) and algebraic geometry (curves of low genus)

Study load

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

Content

**Algebraic Number Theory**

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

**Elliptic Curves**

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

Qualification system

There will be a final exam. Optionally the qualification might be obtained 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

**Matlab**
Mathematical software
34954 - CC - Codes and Cryptography

<table>
<thead>
<tr>
<th>Coordinating unit:</th>
<th>200 - FME - School of Mathematics and Statistics</th>
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</tr>
<tr>
<td>ECTS credits:</td>
<td>7.5 Teainges languages: English</td>
</tr>
</tbody>
</table>

### Teaching staff

- **Coordinator:** SIMEON MICHAEL BALL
- **Others:**
  - Primer quadrimestre:
    - SIMEON MICHAEL BALL - A
    - JAVIER HERRANZ SOTOCA - A

### Prior skills

- Basic probability, basic number theory and linear algebra

### Requirements

- Undergraduate mathematics

### Degree competences to which the subject contributes

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

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

### Teaching methodology

The course is divided in two parts: codes and cryptography. Each part consists of 26 h of ordinary classes, including theory and problem sessions.
Learning objectives of the subject

This course aims to give a solid understanding of the uses of mathematics in Information technologies and modern communications. The course focuses on the reliable and efficient transmission and storage of the information. Both the mathematical foundations and the description of the most important cryptographic protocols and coding systems are given in the course.

Study load

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<tr>
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<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
### Content

#### Introduction

**Learning time:** 6h 15m  
Theory classes: 2h  
Self study: 4h 15m

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

#### Information and Entropy

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

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

#### Source codes without memory

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

**Description:**  

#### Channel coding

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

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

#### Block codes

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

**Description:**  
# 34954 - CC - Codes and Cryptography

<table>
<thead>
<tr>
<th>topic</th>
<th>Learning time</th>
<th>Theory classes</th>
<th>Self study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclic codes</td>
<td>18h 45m</td>
<td>6h</td>
<td>12h 45m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction to modern cryptography</td>
<td>15h 37m</td>
<td>5h</td>
<td>10h 37m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symmetric key cryptography</td>
<td>15h 38m</td>
<td>5h</td>
<td>10h 38m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public key encryption</td>
<td>15h 37m</td>
<td>5h</td>
<td>10h 37m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital signatures</td>
<td>15h 38m</td>
<td>5h</td>
<td>10h 38m</td>
</tr>
<tr>
<td>Description:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Security definitions. RSA and Schnorr signatures.</td>
<td></td>
<td></td>
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</tbody>
</table>
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.

**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.

---

<table>
<thead>
<tr>
<th><strong>Proofs of knowledge and other cryptographic protocols</strong></th>
<th><strong>Learning time:</strong> 15h 37m</th>
</tr>
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<tr>
<td></td>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td></td>
<td>Self study : 10h 37m</td>
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</table>

**Description:**

Ring signatures. Distributed signatures. Identity and attribute based protocols.

<table>
<thead>
<tr>
<th><strong>Multiparty computation</strong></th>
<th><strong>Learning time:</strong> 15h 38m</th>
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<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.
Bibliography

Basic:


Complementary:


34955 - COMB - Combinatorics

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5

Teaching staff
Coordinator: ORIOL SERRA ALBO
Others: Segon quadrimestre: 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: partially ordered sets, extremal set theory, finite geometries, matroids, Ramsey theory and enumerative combinatorics.
### 34955 - COMB - Combinatorics

#### Study load

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

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

<table>
<thead>
<tr>
<th>Topic</th>
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<tbody>
<tr>
<td><strong>Extremal set theory</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado</td>
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</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h 30m</th>
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</thead>
<tbody>
<tr>
<td><strong>Linear algebra methods in combinatorics</strong></td>
<td></td>
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<tr>
<td><strong>Description:</strong></td>
<td>The polynomial method and applications. Fisher's theorem. Equiangular lines, sets with few differences</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time: 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finite geometries</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td>q-anologs of extremal problems. Segre's theorem. Blocking sets, ovals and hyperovals.</td>
</tr>
</tbody>
</table>
### Matroids

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

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

### Probabilistic methods in combinatorics

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

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

### Ramsey theory

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

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

### Enumerative combinatorics

**Learning time:** 32h 30m  
Theory classes: 5h  
Laboratory classes: 5h  
Self study: 22h 30m

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

### Qualification system

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

Basic:


34956 - DG - Discrete and Algorithmic Geometry

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
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: CLEMENS HUEMER
Others: Primer quadrimestre:
        CLEMENS HUEMER - A
        JULIAN THORALF PFEIFLE - A

Prior skills

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

Degree competences to which the subject contributes

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

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. EFFECTIVE USE OF 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.
34956 - DG - Discrete and Algorithmic Geometry

Teaching methodology

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

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

Learning objectives of the subject

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

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

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

Study load

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

<table>
<thead>
<tr>
<th><strong>Preliminaries</strong></th>
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<tr>
<td></td>
<td>Theory classes: 4h</td>
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<td></td>
<td>Self study : 8h 30m</td>
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**Description:**
Computational complexity. Data structures. Representation of geometric objects.

<table>
<thead>
<tr>
<th><strong>Convexity</strong></th>
<th><strong>Learning time:</strong> 19h</th>
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<td>Laboratory classes: 2h</td>
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<tr>
<td></td>
<td>Self study : 13h</td>
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**Description:**
Convex hull computation. Linear programming in low dimensions.

<table>
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<tr>
<th><strong>Decompositions and arrangements</strong></th>
<th><strong>Learning time:</strong> 31h</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 7h</td>
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<td>Laboratory classes: 3h</td>
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<td>Self study : 21h</td>
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**Description:**

<table>
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<th><strong>Proximity Structures</strong></th>
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<td>Laboratory classes: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study : 21h</td>
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**Description:**
Proximity problems. Voronoi diagram, Delaunay triangulation. Shape reconstruction.
### Polytopes and Subdivisions of Point Sets

<table>
<thead>
<tr>
<th>Description:</th>
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</thead>
<tbody>
<tr>
<td>Homogeneous coordinates. Polytopes: faces and boundary structure; examples; operations on polytopes (polarity, products, etc.). Point sets: subdivisions and triangulations (including Delaunay and Voronoi).</td>
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</table>

<table>
<thead>
<tr>
<th>Learning time:</th>
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<tbody>
<tr>
<td>38h</td>
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<tr>
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<tr>
<td>Self study : 25h</td>
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### Lattice Geometry

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Examples of lattices. Ehrhart's Theorem on integer points in polytopes. Brion's Theorem.</td>
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<table>
<thead>
<tr>
<th>Learning time:</th>
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</thead>
<tbody>
<tr>
<td>24h</td>
</tr>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Self study : 16h</td>
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### Symmetry

<table>
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<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Orbifolds and the Magic Theorem on symmetry groups in the plane. Exploitation of symmetry in linear optimization.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Learning time:</th>
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<tbody>
<tr>
<td>23h</td>
</tr>
<tr>
<td>Theory classes: 6h</td>
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<tr>
<td>Practical classes: 1h</td>
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<tr>
<td>Self study : 16h</td>
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### Software

<table>
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<tbody>
<tr>
<td>Polymake, Curved Spaces, etc.</td>
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<table>
<thead>
<tr>
<th>Learning time:</th>
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<tbody>
<tr>
<td>9h</td>
</tr>
<tr>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Self study : 7h</td>
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</table>
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:** 2018
**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:** Primer quadrimestre:
- 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.

**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>Self study:</td>
<td>127h 30m</td>
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<td>68.00%</td>
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### Content

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

**Specific objectives:**

<table>
<thead>
<tr>
<th>Symmetries in graphs</th>
<th>Learning time: 1h</th>
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<tbody>
<tr>
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<table>
<thead>
<tr>
<th>Minors and treewidth</th>
<th>Degree competences to which the content contributes:</th>
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</table>

<table>
<thead>
<tr>
<th>Graphs on surfaces</th>
<th>Degree competences to which the content contributes:</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Graph homomorphisms</th>
<th>Degree competences to which the content contributes:</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Random graphs</th>
<th>Degree competences to which the content contributes:</th>
</tr>
</thead>
</table>
The evaluation of the course is based on the weekly work on problems proposed in the presentation sessions. There will be a final comprehensive exam based on the problem sessions during the course.

**Qualification system**

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

**Bibliography**

**Basic:**


Degree competences to which the subject contributes

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

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

Lectures 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>
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<th>60h</th>
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<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
## Content

### 1 Heat conduction and diffusion

**Learning time:** 56h 15m  
Theory classes: 18h  
Self study: 38h 15m

**Description:**  

### 2 Potentials in physics and technology

**Learning time:** 56h 15m  
Theory classes: 18h  
Self study: 38h 15m

**Description:**  

### 3 Transients in continuous media

**Learning time:** 31h 15m  
Theory classes: 10h  
Self study: 21h 15m

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

### 4 Geometry

**Learning time:** 23h 26m  
Theory classes: 7h 30m  
Self study: 15h 56m

**Description:**  
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:**
- 751 - DECA - Department of Civil and Environmental Engineering
- 749 - MAT - Department of Mathematics

**Academic year:** 2018

**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:** Segon quadrimestre:
- SONIA FERNANDEZ MENDEZ - A
- 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.
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).

**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 in groups to be presented orally 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</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time: 187h 30m</td>
<td>Self study: 127h 30m</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
# Content

## CONTINUUM MECHANICS

**Description:**

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

## COMPUTATIONAL ELASTICITY

**Description:**

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

## COMPUTATIONAL DYNAMICS

**Description:**

**Learning time:** 31h 15m
- Theory classes: 8h
- Practical classes: 2h
- Self study: 21h 15m
### COMPUTATIONAL PLASTICITY AND VISCOELASTICITY

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

### COMPUTATIONAL FLUID DYNAMICS

<table>
<thead>
<tr>
<th>Description:</th>
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</table>

<table>
<thead>
<tr>
<th>Learning time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>31h 15m</td>
</tr>
<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 METHODS FOR WAVE PROBLEMS

<table>
<thead>
<tr>
<th>Description:</th>
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</table>

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

### 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: 2018
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: Primer quadrimestre:
   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.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in
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.

Learning objectives of the subject

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 be held at the computer lab. The SAGE computing environment will be used, with interfaces to Python, R and C if necessary.

Teaching methodology

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>
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</table>
# Mathematical Models in Biology

## Content

<table>
<thead>
<tr>
<th>Mathematical models in Genomics</th>
<th>Learning time: 75h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 12h</td>
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<td></td>
<td>Laboratory classes: 12h</td>
</tr>
<tr>
<td></td>
<td>Self study: 51h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Mathematical Models in Neurophysiology</th>
<th>Learning time: 56h 15m</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 9h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 9h</td>
</tr>
<tr>
<td></td>
<td>Self study: 38h 15m</td>
</tr>
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</table>

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

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

**Description:**
2. One-dimensional discrete models. Chaos in biological systems.
3. Paradigms of population dynamics in current research.
Biological networks

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

Learning time: 18h 45m

- Theory classes: 3h
- Laboratory classes: 3h
- Self study: 12h 45m

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:


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.
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 perturvative 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>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>Learning time: 10h</td>
<td></td>
<td></td>
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<tr>
<td>-------------------------------------------</td>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Invariant objects in Dynamical Systems</strong></td>
<td>Theory classes: 10h</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous and discrete Dynamical Systems.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poincaré map.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Local behaviour of hyperbolic invariant objects. Conjugation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Invariant manifolds.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

| **Normal forms**                          | Learning time: 10h |
|                                          | Theory classes: 10h|
| **Description:**                          |                    |
| Poincaré-Dulac normal forms. Convergence: Poincaré and Siegel domains. | |

| **Perturbation theory in Dynamical Systems**| Learning time: 15h |
|                                            | Theory classes: 15h|
| **Description:**                          |                    |
| Singular pertubation theory.              |                    |

| **Bifurcations**                          | Learning time: 10h |
|                                          | Theory classes: 10h|
| **Description:**                          |                    |
| Local bifurcations for planar vector fields and real maps. Saddle node and Hopf bifurcations. | |
The students have to do some problems (60%) and a research work (25%). There will be also a final exam covering on the theoretical part of the subject (15%). 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 (60%) and a research work (25%). There will be also a final exam covering on the theoretical part of the subject (15%). 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: 2018
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: MARCEL GUARDIA MUNARRIZ
Others:
Segon quadrimestre:
AMADEU DELSHAMS I VALDES - A
MARCEL GUARDIA MUNARRIZ - A

Prior skills

Knowledge of calculus, algebra and ordinary differential equations.

Degree competences to which the subject contributes

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

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

Teaching methodology

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

Learning objectives of the subject
34962 - HS - Hamiltonian Systems

To comprehend the basic foundations of the theory of Hamiltonian systems, and to understand its applications to 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>Self study:</td>
<td>127h 30m</td>
<td></td>
<td>68.00%</td>
</tr>
</tbody>
</table>
# 34962 - HS - Hamiltonian Systems

## Content

<table>
<thead>
<tr>
<th>Description</th>
<th>Learning time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hamiltonian formalism</strong></td>
<td>28h</td>
</tr>
<tr>
<td>Theory classes: 10h</td>
<td></td>
</tr>
<tr>
<td>Self study: 18h</td>
<td></td>
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<tr>
<td><strong>Celestial mechanics</strong></td>
<td>34h</td>
</tr>
<tr>
<td>Theory classes: 12h</td>
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<td>Self study: 22h</td>
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<td><strong>Geometric theory and invariant objects of</strong></td>
<td>24h</td>
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<td>Hamiltonian systems</td>
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<td>Theory classes: 8h</td>
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<td>Self study: 16h</td>
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<td><strong>Integrable systems</strong></td>
<td>10h</td>
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<td>Theory classes: 4h</td>
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<tr>
<td>Self study: 6h</td>
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### Description:
### Quasi-integrable Hamiltonian systems

**Description:**

**Learning time:** 26h
- Theory classes: 8h
- Self study: 18h

### Lagrangian systems and variational methods

**Description:**

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

### Hamiltonian Partial Differential Equations

**Description:**

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

### 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

**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.

Bibliography

**Basic:**


Others resources:

**Hyperlink**

Grup de sistemes dinàmicshttps://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: 2018
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: Segon quadrimestre:
XAVIER CABRE VILAGUT - A
GYULA CSATO - 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.
Teaching methodology

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

Learning objectives of the subject

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

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 60h 32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>127h 30m 68.00%</td>
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Assignments: 0h
## 34963 - ACPDE - Advanced Course in Partial Differential Equations

### Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning time:</th>
<th>Theory classes:</th>
<th>Self study:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical methods for the Poisson and heat equations</td>
<td>47h</td>
<td>15h</td>
<td>32h</td>
</tr>
<tr>
<td>Sobolev spaces and variational methods</td>
<td>47h</td>
<td>15h</td>
<td>32h</td>
</tr>
<tr>
<td>Evolution equations</td>
<td>46h 45m</td>
<td>15h</td>
<td>31h 45m</td>
</tr>
<tr>
<td>Introduction to nonlinear PDEs</td>
<td>46h 45m</td>
<td>15h</td>
<td>31h 45m</td>
</tr>
</tbody>
</table>

**Description:**

- **Classical methods for the Poisson and heat equations:** Maximum principles and Green's functions for the Poisson and heat equations.
- **Sobolev spaces and variational methods:** Basic properties of Sobolev spaces. Weak or variational formulation of boundary problems for linear elliptic PDEs.
- **Introduction to nonlinear PDEs:** Calculus of Variations. Nonlinear eigenvalue problems. Semi-linear elliptic equations.

### Qualification system

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

Bibliography

Basic:


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: 2018
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5  Teaching languages: English

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

Prior skills
Good knowledge of a programming language.

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

Degree competences to which the subject contributes

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

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

**Teaching methodology**

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

**Learning objectives of the subject**

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

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

Qualification system

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

Regulations for carrying out activities

No rules, in principle.

Bibliography

Basic:


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

<table>
<thead>
<tr>
<th>Coordinating unit:</th>
<th>200 - FME - School of Mathematics and Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching unit:</td>
<td>749 - MAT - Department of Mathematics</td>
</tr>
<tr>
<td></td>
<td>751 - DECA - Department of Civil and Environmental Engineering</td>
</tr>
<tr>
<td>Academic year:</td>
<td>2018</td>
</tr>
<tr>
<td>Degree:</td>
<td>MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)</td>
</tr>
<tr>
<td>ECTS credits:</td>
<td>7,5</td>
</tr>
<tr>
<td>Teaching languages:</td>
<td>English</td>
</tr>
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</table>

**Teaching staff**

**Coordinator:** SONIA FERNANDEZ MENDEZ

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

**Teaching methodology**

Lectures, practical work at computer room, exercises and home works.
Learning objectives of the subject

This course is an introduction to numerical methods for the 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.

Study load

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

<table>
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<tr>
<th><strong>Fundamentals of Finite Element Methods (FEM)</strong></th>
<th><strong>Learning time:</strong> 20h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td><strong>Theory classes:</strong> 10h</td>
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<tr>
<td>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.</td>
<td><strong>Laboratory classes:</strong> 10h</td>
</tr>
<tr>
<td>Application to the numerical modelling of flow in porous medium, and potential flow.</td>
<td><strong>Theory classes:</strong> 10h</td>
</tr>
<tr>
<td>Introduction to a posteriori error estimation and adaptivity.</td>
<td><strong>Laboratory classes:</strong> 10h</td>
</tr>
<tr>
<td>Solution of the convection-diffusion equation. Stabilized formulations for convection dominated problems.</td>
<td><strong>Laboratory classes:</strong> 10h</td>
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<table>
<thead>
<tr>
<th><strong>FEM for incompressible flow problems</strong></th>
<th><strong>Learning time:</strong> 6h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td><strong>Theory classes:</strong> 4h</td>
</tr>
<tr>
<td>Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition.</td>
<td><strong>Practical classes:</strong> 2h</td>
</tr>
<tr>
<td>Application to microfluidics and geophysics.</td>
<td><strong>Theory classes:</strong> 4h</td>
</tr>
<tr>
<td>Introduction to the numerical solution of the incompressible Navier-Stokes equations.</td>
<td><strong>Laboratory classes:</strong> 6h</td>
</tr>
<tr>
<td>Introduction to eXtended FEM (X-FEM) for two-phase problems.</td>
<td><strong>Laboratory classes:</strong> 6h</td>
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</table>

<table>
<thead>
<tr>
<th><strong>FEM for wave problems</strong></th>
<th><strong>Learning time:</strong> 10h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td><strong>Theory classes:</strong> 4h</td>
</tr>
<tr>
<td>FEM solution of the 1D wave equation. FEM solution of Helmholtz equation. Non-reflecting boundary conditions.</td>
<td><strong>Laboratory classes:</strong> 6h</td>
</tr>
<tr>
<td>Application to acoustics.</td>
<td><strong>Laboratory classes:</strong> 6h</td>
</tr>
<tr>
<td>Introduction to DG for first order conservation laws. Application to acoustics and electromagnetics.</td>
<td><strong>Laboratory classes:</strong> 6h</td>
</tr>
</tbody>
</table>
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:** 2018

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

**ECTS credits:** 7,5

**Teaching languages:** English

### 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 less 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.
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.
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.

### Transversal:

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. **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.
34966 - VD - Differentiable Manifolds

**Teaching methodology**

Theory classes and tutorial sessions will be used to present and develop the contents of the course. Along the course the students will be given problems to solve as homework.

**Learning objectives of the subject**

The subject focuses on some of the fundamental topics of differential geometry and its applications to different areas including mathematical physics and Dynamical systems.

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**

<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>Self study:</td>
<td>127h 30m</td>
<td>68.00%</td>
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## Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 14h 52m</th>
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<tbody>
<tr>
<td>Complements in Differential Geometry</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>Brief survey of manifold theory and differential geometry including differential forms. We also plan to talk about differentiable distributions and study its integration via the theorem of Frobenius. This will lead us to introducing several examples of foliations.</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 14h 40m</th>
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</thead>
<tbody>
<tr>
<td>Introduction to Differential Topology</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>We present a brief introduction to the theory of Differential Topology which includes basic notions in transversality, singularity theory and Morse theory.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 16h 20m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Lie theory</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>A Lie group is a group endowed with a smooth manifold structure which is compatible with the group operation. In this chapter we provide an introduction to the main aspects of the theory of Lie groups and Lie algebras taking matrix Lie groups as starting point.</td>
<td></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 9h</th>
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</thead>
<tbody>
<tr>
<td>Lie group actions on smooth manifolds</td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong></td>
<td></td>
</tr>
<tr>
<td>We study Lie group actions on smooth manifolds and relate both geometries via the notions of isotropy group and orbit.</td>
<td></td>
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</tbody>
</table>
34966 - VD - Differentiable Manifolds

<table>
<thead>
<tr>
<th>Basic notions on De Rham Cohomology</th>
<th>Learning time: 8h</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study: 5h</td>
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</table>

**Description:**
We define De Rham cohomology and compare it to other cohomologies.

<table>
<thead>
<tr>
<th>Introduction to Symplectic and Poisson Geometry</th>
<th>Learning time: 31h 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td></td>
<td>Self study: 16h 40m</td>
</tr>
</tbody>
</table>

**Description:**
We provide a comprehensive introduction to symplectic and Poisson manifolds with special focus on examples. Starting with symplectic manifolds, we will explain Moser's trick and some applications to normal form theorems such as the Darboux theorem and the classification of symplectic surfaces. We introduce the notion of Hamiltonian vector field, symplectic vector field and Hamiltonian System. Special attention will be given to examples provided by the realm of integrable systems. In particular the action-angle theorem of Arnold-Liouville will be presented and the notion of moment map and Hamiltonian group action. We end the chapter introducing the basic concepts in Poisson geometry (a natural generalization of Symplectic geometry) and proving a decomposition theorem (Weinstein's splitting theorem) in terms of a symplectic leaf of the symplectic foliation.

**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 be 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 \( \text{MAX} \{ \text{exam}, 0.35 \times \text{exam} + 0.40 \times \text{essay} + 0.25 \times \text{exercises} \} \)
Bibliography

Basic:


Complementary:


Others resources:
El master's degree in Advanced Mathematics and Mathematical Engineering (MAMME) és un programa de màster ofertat per la Facultat de Matemàtiques i Estadística (FME) de 60 ECTS, dividits en 45 ECTS de cursos, més 15 ECTS de tesi de màster.

L’oferta de cursos permet als nostres estudiants dissenyar el seu currículum amb dues possibles orientacions: un currículum en matemàtica pura (orientat a recerca en matemàtica fonamental) o un currículum en matemàtica aplicada (preparant els estudiants per a recerca en matemàtica aplicada, y per a treballar en equips interdisciplinaris en col·laboració amb enginyers, físics, biòlegs, economistes, etc).

El MAMME ofereix també la possibilitat de cursar fins a 22.5 ECTS a altres màsters en matemàtiques o estadística, o a altres màsters de la UPC, permetent dissenyar un currículum interdisciplinari basat en la selecció de cursos en màsters en enginyeria o ciències aplicades. Veure les propostes de focalització a http://mamme.masters.upc.edu/en.

### DADES GENERALS

**Durada i inici**
- Un curs acadèmic, 60 crèdits ECTS. Inici: setembre i febrer

**Horaris i modalitat**
- Tarda. Presencial

**Preus i beques**
- Preu aproximat del màster sense expedició del títol, 3.267 € (4.900 € per a no residents a la UE).
- Més informació sobre preus i pagament de la matrícula
- Més informació de beques i ajuts

**Idiomes**
- Anglès

**Lloc d’impartició**
- Facultat de Matemàtiques i Estadística (FME)

**Títol oficial**
- Inscrit en el registre del Ministeri d'Educació, Cultura i Esport

### ACCÉS

**Requisits generals**
- Requisits acadèmics d’accés a un màster

**Places**
- 30

**Preinscripció**
- Preinscripció tancada (consulta els nous períodes de preinscripció al calendari acadèmic).
- Com es formalitza la preinscripció?

**Matrícula**
Com es formalitza la matrícula?

Legalització de documents
Documents expedits per estats no membres de la Unió Europea ni signataris de l’Acord sobre l’espai econòmic europeu han d’estar legalitzats per via diplomàtica o amb la postil·la corresponent.

ACORDS DE DOBLE TITULACIÓ
Amb altres universitats internacionals
- Master’s degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Applied Mathematics (Illinois Institute of Technology). (Flux solament de l’FME a Illinois)

SORTIDES PROFESSIONALS
Sortides professionals
Algunes de les sortides professionals dels titulats i titulades d’aquest màster són la recerca acadèmica (fent un doctorat en matemàtiques, ciència o enginyeria, per exemple), la modelització matemàtica en la indústria, les finances, l’estadística i la recerca aplicada (centres de recerca biomèdica, visió per ordinador, etc.).

Competències

Competències transversals
Les competències transversals descriuen allò que un titulat o titulada és capaç de saber o fer en acabar el procés d’aprenentatge, amb independència de la titulació. Les competències transversals establertes a la UPC són emprendedoria i innovació, sostenibilitat i compromís social, coneixement d’una tercera llengua (preferentment l’anglès), treball en equip i ús solvent dels recursos d’informació.

Competències específiques

1. (Recerca). Llegir i comprendre articles avançats de recerca en matemàtiques. Utilitzar tècniques de recerca en matemàtiques per produir i transmetre nous resultats.
2. (Modelització). Formular, analitzar i validar models matemàtics de problemes pràctics utilitzant les eines matemàtiques més adequades.
3. (Càlcul). Obtenir solucions (exactes o aproximades) a aquests models amb els recursos disponibles, incloent-hi mitjans computacionals.
4. (Avaluació crítica). Discutir la validesa, l’abast i la importància d’aquestes solucions; presentar resultats i defensar conclusions.
5. (Docència). Ensenyar matemàtiques a nivell universitari.

ORGANITZACIÓ

Centre docent UPC
Facultat de Matemàtiques i Estadística (FME)

Responsable acadèmic del programa
Sonia Fernández Méndez

Calendari acadèmic
Calendari acadèmic dels estudis universitaris de la UPC

Normatives acadèmiques
Normativa acadèmica dels estudis de màster de la UPC
<table>
<thead>
<tr>
<th>Assignatures</th>
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<tr>
<td>PRIMER QUADRIMESTRE</td>
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<tr>
<td>Àlgebra Commutativa</td>
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<td>Optativa</td>
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<tr>
<td>Àlgebra No Commutativa</td>
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<td>Mètodes Numèrics per a Equacions en Derivades Parcials</td>
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<td>Modelització Matemàtica amb Equacions en Derivades Parcials</td>
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<td>Mecànica Computacional</td>
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<tr>
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</table>

Novembre 2018. UPC. Universitat Politècnica de Catalunya · BarcelonaTech
El **master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)** (máster universitario en Matemática Avanzada e Ingeniería Matemática) es un programa de máster ofrecido por la Facultad de Matemáticas y Estadística (FME) de 60 ECTS, divididos en 45 ECTS de cursos, más 15 ECTS de tesis de máster.

La oferta de cursos permite a nuestros estudiantes diseñar su currículum con dos posibles orientaciones diferentes: un currículum en matemática pura (orientado a investigación en matemática fundamental) o un currículum en matemática aplicada (preparando los estudiantes para investigación en matemática aplicada, y para trabajar en equipos interdisciplinares en colaboración con ingenieros, físicos, biólogos, economistas, etc).

Además, MAMME ofrece la posibilidad de cursar hasta 22.5 ECTS en otros másteres en matemáticas o estadística, o en otros másteres de la UPC, permitiendo diseñar un currículum interdisciplinar basado en la selección de cursos en másteres en ingeniería o ciencias aplicadas.


<table>
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<th>DATOS GENERALES</th>
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<tbody>
<tr>
<td><strong>Duración e inicio</strong></td>
</tr>
<tr>
<td>Un curso académico, 60 créditos ECTS. Inicio septiembre y febrero</td>
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<tr>
<td><strong>Horarios y modalidad</strong></td>
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<td>Tarde. Presencial</td>
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<td><strong>Precios y becas</strong></td>
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<tr>
<td>Precio aproximado del máster sin la expedición del título, 3.267 € (4.900 € para no residentes en la UE).</td>
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<tr>
<td>Más información sobre precios y pago de la matrícula</td>
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<tr>
<td>Más información de becas y ayudas</td>
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<td><strong>Idiomas</strong></td>
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<td><strong>Lugar de impartición</strong></td>
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<td>Inscrito en el registro del Ministerio de Educación, Cultura y Deporte</td>
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<td><strong>Requisitos generales</strong></td>
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<td><strong>Plazas</strong></td>
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<td><strong>Preinscripción</strong></td>
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<td>Preinscripción cerrada (consulta los nuevos periodos de preinscripción en el <a href="http://mamme.masters.upc.edu/en">calendario académico</a>).</td>
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<td>¿Cómo se formaliza la preinscripción?</td>
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Matrícula
¿Cómo se formaliza la matrícula?

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ACUERDOS DE DOBLE TITULACIÓN
Con otras universidades internacionales
- Master in Advanced Mathematics & Mathematical Engineering (FME) + Master of Science in Applied Mathematics (Illinois Institute of Technology). (Flujo sólo de la FME en Illinois)

SALIDAS PROFESIONALES
Salidas profesionales
Algunas de las salidas profesionales de los titulados de este máster son la investigación académica (haciendo un doctorado en matemáticas, ciencia o ingeniería, por ejemplo), la modelización matemática en la industria, las finanzas, la estadística y la investigación aplicada (centros de investigación biomédica, visión por ordenador, etc.).

Competencias

Competencias transversales
Las competencias transversales describen aquello que un titulado o titulada es capaz de saber o hacer al concluir su proceso de aprendizaje, con independencia de la titulación. Las competencias transversales establecidas en la UPC son la capacidad de espíritu empresarial e innovación, sostenibilidad y compromiso social, conocimiento de una tercera lengua (preferentemente el inglés), trabajo en equipo y uso solvente de los recursos de información.

Competencias específicas
2. (Modelización). Formular, analizar y validar modelos matemáticos de problemas prácticos utilizando las herramientas matemáticas más adecuadas.
3. (Cálculo). Obtener soluciones (exactas o aproximadas) a estos modelos con los recursos disponibles, incluyendo medios computacionales.
4. (Evaluación crítica). Discutir la validez, el alcance y la importancia de estas soluciones; presentar resultados y defender conclusiones.
5. (Docencia). Enseñar matemáticas a nivel universitario.

ORGANIZACIÓN
Centro docente UPC
Facultad de Matemáticas y Estadística (FME)

Responsable académico del programa
Sonia Fernández Méndez

Calendario académico
Calendario académico de los estudios universitarios de la UPC

Normativas académicas
Normativa académica de los estudios de máster de la UPC
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