Guia Docent

20/21

Facultat de Matemàtiques i Estadística

Master in Advanced Mathematics and Mathematical Engineering

1820-1910

Curs Nightingale
MÀSTER MAMME

Sumari

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   - General information MAMME
   - Study program
   - MAMME courses
   - Master thesis
   - Focus proposals
   - Subjects Master MAMME

➢ Català
   - Informació general

➢ Español
   - Información geeral
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.

GENERAL DETAILS

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

Timetable and delivery
Afternoons. Face-to-face

Fees and grants
Approximate fees for the master's degree, excluding other costs, €2,766 (€4,149 for non-EU residents).
More information about fees and payment options
More information about grants and loans

Language of instruction
English

Location
School of Mathematics and Statistics (FME)

Official degree
Recorded in the Ministry of Education's degree register

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-exhaustive, 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.

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 modelling 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: ACADEMIC CALENDAR AND REGULATIONS
## 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>Commutative Algebra</td>
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<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>
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</tr>
<tr>
<td>Algebraic Geometry</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Codes and Cryptography</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>
<tr>
<td>Machine Learning</td>
<td>7.5</td>
<td>Optional</td>
</tr>
<tr>
<td>Seminar on Algebra, Geometry and Discrete Mathematics</td>
<td>3</td>
<td>Optional</td>
</tr>
<tr>
<td>Seminar on Analysis, Differential Equations and Modelling</td>
<td>3</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**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)
- Algebraic Geometry (Spring term Q2)
- Differentiable Manifolds (Spring term Q2)
- Number Theory (Autumn term Q1)
- Non-Commutative Algebra (Autumn term Q1)

**Field: Discrete Mathematics and Algorithmics**
- Codes and Cryptography (Spring term Q2)
- 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 (Spring term Q1)
- Machine Learning (Spring term Q2)

**Interdisciplinary seminars (3 ECTS each seminar)**
- Seminar on algebra, geometry and discrete mathematics (Spring term Q2)
- Seminar on analysis, differential equations and modelling (Spring term Q2)
Master's thesis

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

A list of proposals for master thesis can be found at the FME intranet at Borsa de Projectes. Even though the list includes many proposals, other researchers not included there will also be willing to supervise your work. Thus, if you are interested in a particular area, you can contact the coordinator or the course closer to it, or the master's director or a member of the academic committee for guidance.

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
- Master Thesis evaluation

Forthcoming defenses

A list of forthcoming presentations of master's thesis can be found at this link.

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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, María, Martí, Pere-Daniel, Santi, Víctor, Xevi, 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>Location</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 "Geometria Algebraica" of Grau en Matemàtiques at FME.

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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 an 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.

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

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

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**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>Course</th>
<th>Credits</th>
<th>Language</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative and quantitative methods in dynamical systems</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<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>6 ECTS</td>
<td>English</td>
<td>Master’s degree in advanced and professional mathematics (UB)</td>
</tr>
</tbody>
</table>

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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>
</tr>
<tr>
<td>Differentiable Manifolds</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>Local Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

A minimum of 3 MAMME courses (22.5 ECTS) is mandatory.
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 modeling with PDEs are invited to select 45 ECTS from this list:

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Master's Degree</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.

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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.

### Courses Offered

<table>
<thead>
<tr>
<th>Course Description</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 bioinformática</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>Course</td>
<td>ECTS</td>
<td>Language</td>
<td>Master Program</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>------</td>
<td>----------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Numerical Modeling*</td>
<td>9</td>
<td>English</td>
<td>Master in Engineering of Roads, Canals and Ports, UPC</td>
</tr>
<tr>
<td>Técnicas báscicas en neurociencia**</td>
<td>5</td>
<td></td>
<td>Master official in Neuroscience, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Biología Celular y Molecular de la Neurona**</td>
<td>5</td>
<td></td>
<td>Master official in Neuroscience, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Diseño y análisis de datos en neurociencia cognitiva**</td>
<td>2.5</td>
<td></td>
<td>Master official in Neuroscience, UB-UPF-UDL-URV</td>
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<td>Neurociencia computacional**</td>
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</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.

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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).

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

C. Pau Gargallo, 14. 08028 Barcelona - Tel.: 93 401 58 80
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 to 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.

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>
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<tr>
<td>Advanced course in PDEs</td>
<td>7.5</td>
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<td>Mathematical Modeling with PDEs</td>
<td>7.5</td>
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<td>9</td>
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</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.
Master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)

El master's degree in Advanced Mathematics and Mathematical Engineering (MAMME) (màster universitari en Matemàtica Avançada i Enginyeria Matemàtica) 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, i 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.

**Legalització de documents**

Els 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.**

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**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)

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**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 ha de saber o ha de ser capaç de 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.

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**ORGANITZACIÓ ACADÈMICA: NORMATIVES, CALENDARIS**

**Centre docent UPC**
Facultat de Matemàtiques i Estadística (FME)

**Responsible acadèmic del programa**
Juan José Rue Perna

**Calendari acadèmic**
Calendari acadèmic dels estudis universitaris de la UPC

**Normatives acadèmiques**
Normativa acadèmica dels estudis de màster de la UPC

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**PLA D’ESTUDIS**

<table>
<thead>
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2 / 3
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Novembre 2020. **UPC**. Universitat Politècnica de Catalunya · BarcelonaTech
Master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)

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 interdisciplinarios 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.


DATOS GENERALES

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ACCESO

Requisitos generales
Requisitos académicos de acceso a un máster

Plazas de
30

Preinscripción
Preinscripción cerrada (consulta los nuevos periodos de preinscripción en el calendario académico). ¿Cómo se formaliza la preinscripción?

Matrícula
¿Cómo se formaliza la matrícula?
Legalización de documentos
Los documentos expedidos por estados no miembros de la Unión Europea ni firmantes del Acuerdo sobre el espacio económico europeo tienen que estar legalizados por vía diplomática o con correspondiente apostilla.

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 ACADÉMICA: NORMATIVAS, CALENDARIOS

Centro docente UPC
Facultad de Matemáticas y Estadística (FME)

Responsable académico del programa
Juan José Rue Perna

Calendario académico
Calendario académico de los estudios universitarios de la UPC

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

PLAN DE ESTUDIOS
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<th>Asignaturas</th>
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Noviembre 2020. **UPC. Universitat Politècnica de Catalunya · BarcelonaTech**
Index

34963 - Advanced Course in Partial Differential Equations
34952 - Algebraic Geometry
34954 - Codes and Cryptography
34955 - Combinatorics
34950 - Commutative Algebra
34959 - Computational Mechanics
34966 - Differentiable Manifolds
34956 - Discrete and Algorithmic Geometry
34957 - Graph Theory
34962 - Hamiltonian Systems
200900 - Machine Learning
34958 - Mathematical Modelling with Partial Differential Equations
34960 - Mathematical Models in Biology
34951 - Non-Commutative Algebra
34953 - Number Theory
34964 - Numerical Methods for Dynamical Systems
34965 - Numerical Methods for Partial Differential Equations
34961 - Quantitative and Qualitative Methods in Dynamical Systems
200901 - Seminar on Algebra, Geometry and Discrete Mathematics
200902 - Seminar on Analysis, Differential Equations and Modelling
Course guides
34963 - ACPDE - Advanced Course in Partial Differential Equations

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
981 - CRM - Mathematical Research Centre.

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

Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: ALBERT MAS BLESA

Others: Segon quadrimestre:
XAVIER CABRE VILAGUT - A
JUAN CARLOS FELIPE NAVARRO - A
ALBERT MAS BLESA - A

PRIOR SKILLS

Basic knowledge of Partial Differential Equations (undergraduate level).
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

This course is intended to be an introduction to modern methods for solving elliptic partial differential equations. However, some insights to classical solutions to parabolic and hyperbolic equations will also be given. The objectives of the course are:
- understand the classical methods to solve the transport, wave, heat, Laplace, and Poisson equations,
- understand the role of Sobolev norms and compact embeddings to solve PDEs and find spectral decompositions,
- learn the modern methods to solve elliptic PDEs.

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
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<tr>
<td>Self study</td>
<td>127.5</td>
<td>68.00</td>
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<tr>
<td>Hours large group</td>
<td>60.0</td>
<td>32.00</td>
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**Total learning time:** 187.5 h

CONTENTS

- **Classical methods in PDEs**
  **Description:** [This topic will only be treated in the exercises sessions.] Classical solutions to the transport, wave, heat, Laplace, and Poisson equations. Maximum principles, Green’s functions, separation of variables, energy methods, probabilistic interpretation.
  **Full-or-part-time:** 46h
  - Theory classes: 15h
  - Self study: 31h

- **Hilbert space techniques**
  **Description:** Orthogonal projections, Riesz-Fréchet representation theorem, Lax-Milgram theorem.
  **Full-or-part-time:** 25h
  - Theory classes: 8h
  - Self study: 17h

- **Sobolev spaces**
  **Description:** Mollifiers, Fréchet-Kolmogorov theorem, distributions, Sobolev norms, Poincaré inequality, compact embeddings, approximation by smooth functions, traces.
  **Full-or-part-time:** 29h
  - Theory classes: 9h
  - Self study: 20h
Weak formulation and the weak maximum principle
Description:
Weak solutions via Hilbert space techniques and interpretation, comparison principles in the weak formulation.
Full-or-part-time: 25h
Theory classes: 8h
Self study: 17h

Regularity theory
Description:
Boundedness of weak solutions, Sobolev-Gagliardo-Nirenberg inequality, regularity in Sobolev spaces, the translation method, bootstrap technique.
Full-or-part-time: 25h 30m
Theory classes: 8h
Self study: 17h 30m

Eigenvalues
Description:
Spectral decompositions, applications to (time dependent) evolution equations, Rayleigh quotient, description of the first eigenvalue for the Dirichlet problem on a bounded domain.
Full-or-part-time: 17h
Theory classes: 6h
Self study: 11h

Nonlinear problems
Description:
Calculus of variations, monotone iteration method, obstacle problems.
Full-or-part-time: 20h
Theory classes: 6h
Self study: 14h

GRADING SYSTEM
The evaluation of the course is based on:
- the resolution of problems proposed in class (40%),
- a midterm exam (20%),
- a final comprehensive exam (40%).
The active participation during the course will be a requirement for the evaluation of the final exam.
BIBLIOGRAPHY

Basic:

Complementary:
Course guides
34952 - AG - Algebraic Geometry

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).

Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: PEDRO PASCUAL GAINZA

Others: Segon quadrimestre: PEDRO PASCUAL GAINZA - A

PRIOR SKILLS

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

REQUIREMENTS

Basic abstract Algebra, Topology and Differential Geometry.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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

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

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</tr>
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</table>

Total learning time: 187.5 h

CONTENTS

Chapter 1: Algebraic equations

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.

Full-or-part-time: 15h
Theory classes: 6h
Self study: 9h

Chapter 2: Algebraic varieties

Description:

Full-or-part-time: 13h
Theory classes: 6h
Self study: 7h

Chapter 3: Projective varieties

Full-or-part-time: 9h
Theory classes: 4h
Self study: 5h

Chapter 4: Maps and morphisms

Description:

Full-or-part-time: 13h
Theory classes: 6h
Self study: 7h
Chapter 5: Complex analytic varieties

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

Full-or-part-time: 14h
Theory classes: 8h
Self study: 6h

Chapter 6: Sheaves

Description:
Sheaves on a paracompact topological space, cohomology. Coherent sheaves on an algebraic variety: the canonical and hyperplane section sheaves, Riemann-Roch for curves. The Dolbeault complex over a complex analytic manifold: Hodge theory.

Full-or-part-time: 18h
Theory classes: 8h
Self study: 10h

Chapter 7: Final projects

Description:
The topics of the final projects made by course students, explained by themselves and by the course lecturer.

Full-or-part-time: 12h
Theory classes: 4h
Self study: 8h

GRADING 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.

EXAMINATION RULES.

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:

Complementary:
- Voisin, Claire. Hodge theory and complex algebraic geometry 1. Cambridge U.P.,
**Course guides**

**34954 - CC - Codes and Cryptography**

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.

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

Academic year: 2020  
ECTS Credits: 7.5  
Languages: English

**LECTURER**

Coordinating lecturer: SIMEON MICHAEL BALL

Others:  
Segon 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.
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**

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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</table>

Total learning time: 187.5 h

CONTENTS

**Introduction**

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

**Full-or-part-time:** 6h 15m
Theory classes: 2h
Self study : 4h 15m

**Information and Entropy**

Description:
Uncertainty or information. Entropy. Mutual information

**Full-or-part-time:** 18h 45m
Theory classes: 6h
Self study : 12h 45m

**Source codes without memory**

Description:

**Full-or-part-time:** 12h 30m
Theory classes: 4h
Self study : 8h 30m

**Channel coding**

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

**Full-or-part-time:** 18h 45m
Theory classes: 6h
Self study : 12h 45m
## Block codes

**Description:**

**Full-or-part-time:** 18h 45m  
Theory classes: 6h  
Self study : 12h 45m

## Cyclic codes

**Description:**

**Full-or-part-time:** 18h 45m  
Theory classes: 6h  
Self study : 12h 45m

## Introduction to modern cryptography

**Description:**

**Full-or-part-time:** 15h 37m  
Theory classes: 5h  
Self study : 10h 37m

## Symmetric key cryptography

**Description:**

**Full-or-part-time:** 15h 38m  
Theory classes: 5h  
Self study : 10h 38m

## Public key encryption

**Description:**

**Full-or-part-time:** 15h 37m  
Theory classes: 5h  
Self study : 10h 37m
Digital signatures

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

**Full-or-part-time:** 15h 38m
- Theory classes: 5h
- Self study: 10h 38m

Proofs of knowledge and other cryptographic protocols

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

**Full-or-part-time:** 15h 37m
- Theory classes: 5h
- Self study: 10h 37m

Multiparty computation

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

**Full-or-part-time:** 15h 38m
- Theory classes: 5h
- Self study: 10h 38m

**GRADING 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.

**EXAMINATION RULES.**

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

**BIBLIOGRAPHY**

**Basic:**

**Complementary:**
Course guides
34955 - COMB - Combinatorics

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.

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

Academic year: 2020   ECTS Credits: 7.5   Languages: English

LECTURER
Coordinating lecturer: ORIOL SERRA ALBO

Others:
Segon quadrimestre:
MARCOS NOY SERRANO - A
JUAN JOSÉ RUE PERNA - A
ORIOL SERRA ALBO - A

PRIOR SKILLS
Basic calculus and linear algebra. Notions of probability.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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

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

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

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Total learning time: 187.5 h

CONTENTS

### Partially ordered sets

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

**Full-or-part-time:** 24h 40m

- Practical classes: 4h
- Laboratory classes: 4h
- Self study: 16h 40m

### Extremal set theory

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

**Full-or-part-time:** 24h 40m

- Theory classes: 4h
- Laboratory classes: 4h
- Self study: 16h 40m

### Linear algebra methods in combinatorics

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

**Full-or-part-time:** 18h 30m

- Theory classes: 3h
- Laboratory classes: 3h
- Self study: 12h 30m

### Finite geometries

**Description:**

**Full-or-part-time:** 18h 30m

- Theory classes: 3h
- Laboratory classes: 3h
- Self study: 12h 30m
Matroids

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

Full-or-part-time: 18h 30m
Theory classes: 3h
Laboratory classes: 3h
Self study: 12h 30m

Probabilistic methods in combinatorics

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

Full-or-part-time: 18h 30m
Theory classes: 3h
Laboratory classes: 3h
Self study: 12h 30m

Ramsey theory

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

Full-or-part-time: 31h 40m
Theory classes: 5h
Laboratory classes: 5h
Self study: 21h 40m

Enumerative combinatorics

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

Full-or-part-time: 32h 30m
Theory classes: 5h
Laboratory classes: 5h
Self study: 22h 30m

GRADING SYSTEM

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

Basic:
Course guides
34950 - CALG - Commutative Algebra

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER
Coordinating lecturer: FRANCESC D'ASSIS PLANAS VILANOVA
Others: Primer quadrimestre: FRANCESC D'ASSIS PLANAS VILANOVA - A

PRIOR SKILLS
Linear algebra, algebraic structures, topology.

REQUIREMENTS
The two first years of a degree in mathematics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
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6. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

TEACHING METHODOLOGY
Teaching Classes, resolution of problems
LEARNING OBJECTIVES OF THE SUBJECT

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

STUDY LOAD

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</table>

Total learning time: 187.5 h

CONTENTS

Rings and ideals

Description:
Basics on ring theory and ideals.

Full-or-part-time: 28h 20m
Theory classes: 15h
Self study : 13h 20m

Modules

Description:
General properties of modules.
Modules of fractions. Chain conditions. Homomorphisms and tensor product.

Full-or-part-time: 24h
Theory classes: 12h
Self study : 12h

Algebraic varieties

Description:
The spectrum of a ring. Zariski topology.

Full-or-part-time: 24h
Theory classes: 12h
Self study : 12h

Introduction to homological algebra

Description:

Full-or-part-time: 24h
Theory classes: 12h
Self study : 12h
Local algebra

Description:
Regular sequences. Depth.
Homological characterizations.
Regular rings, Gorenstein rings, Cohen-Macaulay rings

Full-or-part-time: 18h 40m
Theory classes: 9h
Self study : 9h 40m

GRADING SYSTEM

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

If necessary, a final exam

BIBLIOGRAPHY

Basic:
Course guides
34959 - CM - Computational Mechanics

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
751 - DÉCA - Department of Civil and Environmental Engineering.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).
Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: JOSE JAVIER MUÑOZ ROMERO

Others: Segon quadrimestre:
SONIA FERNANDEZ MENDEZ - A
ALBA MUIXÍ BALLONGA - 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.
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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

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

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Total learning time: 187.5 h

CONTENTS

CONTINUUM MECHANICS

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study : 21h 15m

COMPUTATIONAL ELASTICITY

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study : 21h 15m
COMPUTATIONAL DYNAMICS

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study: 21h 15m

COMPUTATIONAL PLASTICITY AND VISCOELASTICITY

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study: 21h 15m

COMPUTATIONAL FLUID DYNAMICS

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study: 21h 15m

COMPUTATIONAL METHODS FOR WAVE PROBLEMS

Description:

Full-or-part-time: 31h 15m
Theory classes: 8h
Practical classes: 2h
Self study: 21h 15m
GRADING SYSTEM

Final exam (40%), assignment problems (30%), and course project (30%, evaluated with an oral presentation and a written report).

BIBLIOGRAPHY

Basic:

Complementary:
Course guides

34966 - VD - Differentiable Manifolds

Last modified: 17/06/2020

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.

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

Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: EVA MIRANDA GALCERAN
Others: Segon quadrimestre:
EVA MIRANDA GALCERAN - A
CEDRIC OMS - A

PRIOR SKILLS

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

This is not a basic course and the students are assumed to have attended previous courses on differential geometry and smooth manifolds. Students feeling that they may not fulfill the requisites are invited to discuss their case with the lecturers. It is totally possible for prospective students with 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.

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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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.

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>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>127.5</td>
<td>68.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>60.0</td>
<td>32.00</td>
</tr>
</tbody>
</table>

Total learning time: 187.5 h

CONTENTS

Complements in Differential Geometry

Description:
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.

Full-or-part-time: 14h 52m
Theory classes: 6h
Self study : 8h 52m

Introduction to Differential Topology

Description:
We present a brief introduction to the theory of Differential Topology which includes basic notions in transversality, singularity theory and Morse theory.

Full-or-part-time: 14h 40m
Theory classes: 8h
Self study : 6h 40m

Introduction to Lie theory

Description:
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.

Full-or-part-time: 16h 20m
Theory classes: 8h
Self study : 8h 20m
### Lie group actions on smooth manifolds

**Description:**
We study Lie group actions on smooth manifolds and relate both geometries via the notions of isotropy group and orbit.

**Full-or-part-time:** 18h
- Theory classes: 4h
- Theory classes: 4h
- Self study: 5h
- Self study: 5h

### Basic notions on De Rham Cohomology

**Description:**
We define De Rham cohomology and compare it to other cohomologies. (Depending on the preliminary knowledge of the students, this chapter may be considered as an APPENDIX)

**Full-or-part-time:** 8h
- Theory classes: 3h
- Self study: 5h

### Introduction to Symplectic and Poisson Geometry

**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.

**Full-or-part-time:** 31h 40m
- Theory classes: 15h
- Self study: 16h 40m

---

**GRADING SYSTEM**

There will be exam(s) which will contribute to the final grade in a 50% and an essay that will contribute to the final grade in another 50%. Students would choose, together with the lecturers, a topic that complements or advances the material taught during the course, according to their mathematical interests.

**EXAMINATION RULES.**

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

50% exam(s) + 50% essay

The grade "exam(s)" includes the one of final exam but may also include other examination material such as ATENEA questionnaires or take-home exercises. The choices and number of exams will depend on several factors including the ratio presental versus online teaching.
BIBLIOGRAPHY

Basic:
- Eva Miranda, Pau Mir and Cédric Oms. Notes of the course.

Complementary:

RESOURCES

Other resources:
Notes on the Geometry and Dynamics of singular symplectic manifolds (notes on the FSMP course by Eva Miranda)

Course on youtube by Professor Eva Miranda on Lie group actions
https://www.youtube.com/channel/UC8Fzyf58s0EiZ-gdYgz2ghw?view_as=subscriber
Course on youtube by Professor Eva Miranda on Symplectic and Poisson Geometry
https://www.youtube.com/channel/UC8Fzyf58s0EiZ-gdYgz2ghw?view_as=subscriber
Course guides
34956 - DG - Discrete and Algorithmic Geometry

Last modified: 14/06/2020

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).
Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: RODRIGO IGNACIO SILVEIRA ISOBA

Others:
Primer quadrimestre:
CLEMENS HUEMER - A
JULIAN THORALF PFEIFLE - A
RODRIGO IGNACIO SILVEIRA ISOBA - 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.
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

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</table>

Total learning time: 187.5 h

CONTENTS

Preliminaries

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

Full-or-part-time: 12h 30m
Theory classes: 4h
Self study : 8h 30m
### Convexity
**Description:**
Convex hull computation. Linear programming in low dimensions.

**Full-or-part-time:** 19h  
Theory classes: 4h  
Laboratory classes: 2h  
Self study: 13h

### Decompositions and arrangements
**Description:**

**Full-or-part-time:** 31h  
Theory classes: 7h  
Laboratory classes: 3h  
Self study: 21h

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

**Full-or-part-time:** 31h  
Theory classes: 7h  
Laboratory classes: 3h  
Self study: 21h

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

**Full-or-part-time:** 38h  
Theory classes: 10h  
Laboratory classes: 3h  
Self study: 25h

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

**Full-or-part-time:** 24h  
Theory classes: 6h  
Laboratory classes: 2h  
Self study: 16h
### Symmetry

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

**Full-or-part-time:** 23h  
- Theory classes: 6h  
- Practical classes: 1h  
- Self study : 16h

### Software

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

**Full-or-part-time:** 9h  
- Laboratory classes: 2h  
- Self study : 7h

### Grading System

The course consists in two parts, each contributes with 50 % to the final grade. For each part: Students will obtain marks by turning in their solutions to problems from the problem sets (50%), by presenting solutions to problems or a research paper (15 %), and there will be an exam (35 %).

### Bibliography

**Basic:**

**Complementary:**
RESOURCES

Audiovisual material:
Course guides
34957 - GT - Graph Theory

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: MARCOS NOY SERRANO
Others:
   Primer quadrimestre: 
   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:
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8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

TEACHING METHODOLOGY

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

Extremal 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

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</tbody>
</table>

Total learning time: 187.5 h

CONTENTS

Spectral techniques in Graph Theory

Description:

Specific objectives:

Full-or-part-time: 12h
Theory classes: 12h

Symmetries in graphs

Description:
Vertex symmetric and Edge symmetric graphs. Cayley graphs. Highly symmetric graphs

Specific objectives:

Full-or-part-time: 1h
Theory classes: 1h

Minors and treewidth

Description:

Specific objectives:
Classes defined by forbidden minors. Serie-Parallel graphs. k-trees and tree width.

Full-or-part-time: 11h
Theory classes: 11h
Graphs on surfaces

**Description:**

**Specific objectives:**
Euler formula. Planar separator theorem

**Full-or-part-time:** 4h
Theory classes: 4h

Graph homomorphisms

**Description:**
Graph homomorphisms. Retracts and Cores. The homomorphism order. Antichains.

**Specific objectives:**
Homomorphisms and colorings. Fractional and circular chromatic numbers.

**Full-or-part-time:** 6h
Theory classes: 6h

Random graphs

**Description:**

**Specific objectives:**
Graphs with large girth and large chromatic number. Expansion properties of random graphs. Threshold for connectivity. The Poisson paradigm.

**Full-or-part-time:** 12h
Theory classes: 12h

Extremal Graph Theory

**Description:**

**Specific objectives:**
Counting Lemma and Removal Lemma. Applications of Szemerédi regularity Lemma.

**Full-or-part-time:** 12h
Theory classes: 12h

**GRADING SYSTEM**

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

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

BIBLIOGRAPHY

Basic:
- Alon, Noga; Spencer Joel. The Probabilistic Method. 2016. Wiley,

Complementary:
Course guides
34962 - HS - Hamiltonian Systems

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.

Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).

Academic year: 2020  ECTS Credits: 7.5  Languages: English

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

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

LEARNING OBJECTIVES OF THE SUBJECT
To comprehend the basic foundations of the theory of Hamiltonian systems, and to understand its applications to Celestial Mechanics and other fields.
## STUDY LOAD

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

**Total learning time:** 187.5 h

## CONTENTS

### Hamiltonian formalism

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

**Full-or-part-time:** 28h
- Theory classes: 10h
- Self study: 18h

### Celestial mechanics

**Description:**

**Full-or-part-time:** 34h
- Theory classes: 12h
- Self study: 22h

### Geometric theory and invariant objects of Hamiltonian systems

**Description:**

**Full-or-part-time:** 24h
- Theory classes: 8h
- Self study: 16h

### Integrable systems

**Description:**

**Full-or-part-time:** 10h
- Theory classes: 4h
- Self study: 6h
<table>
<thead>
<tr>
<th>Course Title</th>
<th>Description</th>
<th>Full-or-part-time</th>
<th>Theory classes</th>
<th>Self study</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Interactions between Dynamical Systems and Partial Differential Equations</td>
<td>Summer School and Research workshop on topics between Dynamical Systems and Partial Differential Equations</td>
<td>49h 30m</td>
<td>12h</td>
<td>37h 30m</td>
</tr>
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</table>

**ACTIVITIES**

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>Description</th>
<th>Specific objectives</th>
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</thead>
<tbody>
<tr>
<td>JISD summer school</td>
<td>Attendance to the JISD summer school</td>
<td>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.</td>
</tr>
</tbody>
</table>
GRADING 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:

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
Course guides
200900 - ML - Machine Learning

Last modified: 28/06/2020

Unit in charge: School of Mathematics and Statistics
Teaching unit: 723 - CS - Department of Computer Science.
715 - EIO - Department of Statistics and Operations Research.

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

Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: LUIS ANTONIO BELANCHE MUÑOZ
Others: Segon quadrimestre:
LUIS ANTONIO BELANCHE MUÑOZ - A
PEDRO FRANCISCO DELICADO USEROS - A

PRIOR SKILLS
The student should have knowledge of fundamental mathematical topics, such as linear algebra, calculus, probability distributions, optimization and basic (linear) statistical methods.

REQUIREMENTS
The student should have knowledge of basic machine learning concepts. These concepts can be acquired simultaneously, for example being enrolled in the "Statistical Learning" subject offered in the MESIO master.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES
Specific:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

TEACHING METHODOLOGY
On-Site Learning: On-site learning will be organized into theoretical-practical sessions. All these sessions will be held in a standard classroom, although students should bring their own laptops. Lectures will normally combine a 75% of expository classes and another 25% of guided practical work. In the expository part of the sessions, the theoretical aspects are presented and discussed and accompanied by practical examples, using slides that will be previously supplied to the student. The fundamental work environment of the practical part of the sessions will be R, of which an intermediate knowledge is presumed (use of the environment and basic programming).

Off-Site Learning: Off-site learning will consist of the study and resolution of (mainly practical) problems that the student should turn in throughout the course. Some of these exercises will require completion of programming tasks in R and preparation of short reports using RMarkdown (or a similar tool).
LEARNING OBJECTIVES OF THE SUBJECT

Upon completion of the course, the student should have acquired advanced competences on the general topics of statistical machine learning and unsupervised topics, specially data visualization. In particular, the student should be able to produce machine learning solutions for many complex problems, including those in which a reduction of dimension is necessary, those where the data comes as variables of different mixed types, or those where the number of variables greatly exceeds the number of observations, such as problems typically found in genomics.

STUDY LOAD

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**Total learning time:** 187.5 h

CONTENTS

**Introduction to unsupervised learning**

**Description:**
Definition and illustrative examples of unsupervised learning

**Full-or-part-time:** 2h
Theory classes: 2h

**Nonlinear dimensionality reduction**

**Description:**
a. Principal curves.
b. Local Multidimensional Scaling.
c. ISOMAP.
d. t-Stochastic Neighbor Embedding.
e. Applications

**Full-or-part-time:** 8h
Theory classes: 4h
Laboratory classes: 4h

**Dimensionality reduction with sparsity**

**Description:**
a. Matrix decompositions, approximations, and completion.
b. Sparse Principal Components and Canonical Correlation.
c. Applications

**Full-or-part-time:** 8h
Theory classes: 4h
Laboratory classes: 4h
General introduction to machine learning

Description:
Introduction to Bayesian thinking for machine learning. Learning by solving a regularized problem. Illustrative example.

Full-or-part-time: 5h
Theory classes: 2h
Practical classes: 3h

Learning in functional spaces

Description:

Full-or-part-time: 8h
Theory classes: 4h
Practical classes: 4h

Kernel functions in R^d

Description:
Description and demonstration of fundamental kernel functions in R^d. Polynomial and Gaussian kernels. General properties of kernel functions.

Full-or-part-time: 4h
Theory classes: 2h
Practical classes: 2h

The support vector machine for classification, regression and novelty detection

Description:
The support vector machine (SVM) is the flagship in kernel methods. Its versions for classification, regression and novelty detection are explained and demonstrated.

Full-or-part-time: 6h
Theory classes: 4h
Practical classes: 2h

Kernel functions for different data types

Description:
Some kernel functions for different data types are presented and demonstrated, such as text, trees, graphs, categorical variables, and others.

Full-or-part-time: 6h
Theory classes: 4h
Practical classes: 2h
Other kernel-based learning algorithms

**Description:**
Additional kernel-based learning methods are explained, such as kernel PCA and kernel FDA. These are illustrated in several application examples.

**Full-or-part-time:** 5h
Theory classes: 3h
Practical classes: 2h

Advanced ideas and techniques in kernel-based learning methods

**Description:**
Other advanced methods are briefly introduced, such as the RVM and GPs. Nyström acceleration and random Fourier features.
Introduction to the idea of Deep Kernel Learning

**Full-or-part-time:** 2h
Theory classes: 2h

**GRADING SYSTEM**

The grading method will be based in two basic marks, as follows:

1) Pr done through the course: 50%
2) Final exam: 50%

The practical work will consist in a term project as well as several exercises, all of which can be done in groups (their format will be specified onsite), but the exam is completed as an individual task.

**EXAMINATION RULES.**

The precise format for the exam will be specified with sufficient advance. It may include restrictions on the allowed knowledge sources, such as written notes, books, internet connection, etc.

**BIBLIOGRAPHY**

**Basic:**

**Complementary:**
Course guides
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER
Coordinating lecturer: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ
Others: Primer quadrimestre:
XAVIER CABRE VILAGUT - A
JEZABEL CURBELO HERNANDEZ - A
JAIME HARO CASES - A
JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ - A

PRIOR SKILLS
* Good knowledge of Calculus techniques, including integral theorems and basic Complex Variable methods.
* Elementary solution of PDEs and ODEs.
* Some experience on simple cases of mathematical modelling, especially in classical physics (gravitation, heat conduction, mechanics or electromagnetism).

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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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 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

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Total learning time: 187.5 h

CONTENTS

1. Heat conduction and diffusion

Description:
Boundary conditions, Energy Functionals, separation of variables, Thin domains, Convergence to gaussians, entropy
Steffan Problem, Black-Scholes model, Reaction-diffusion. Fractional diffusion.

Full-or-part-time: 56h 15m
Theory classes: 18h
Self study : 38h 15m

2. Potentials in physics and technology

Description:
Classical gravitation, electrostatics, volume and layer potentials
Euler equations of inviscid fluids and potential flows.
Complex analysis methods in plane potential flows. Lift and drag.
Navier-Stokes system and the viscous contribution to drag. Stokes and Boundary layer equations.

Full-or-part-time: 56h 15m
Theory classes: 18h
Self study : 38h 15m
### 3 Transients in continuous media

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

**Full-or-part-time:** 31h 15m  
Theory classes: 10h  
Self study: 21h 15m

### 4 Cosmological Models in Mathematical Physics

**Description:**
Big Bang Cosmology  
Inflation  
The current cosmic acceleration

**Full-or-part-time:** 32h 09m  
Theory classes: 10h  
Self study: 22h 09m

### 5 Introduction to Calculus of Variations

**Description:**
Introduction to Calculus of Variations

**Full-or-part-time:** 12h 52m  
Theory classes: 4h  
Self study: 8h 52m

---

**GRADING 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:**
Course guides
34960 - MMB - Mathematical Models in Biology

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTORER

Coordinating lecturer: ANTONI GUILLAMON GRABOLOSA

Others:
Primer quadrimestre:
MARTA CASANELLAS RIUS - A
JESUS FERNANDEZ SANCHEZ - A
ANTONI GUILLAMON GRABOLOSA - A
JOSE TOMAS LAZARO OCHOA - 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 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

The course will be structured in five blocks each consisting of a brief introduction through theoretical lectures, the development of a short project in groups and wrap-up sessions with oral presentations, discussion and complementary lectures. The central part intended to develop the short project will held at the computer lab.

LEARNING OBJECTIVES OF THE SUBJECT

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

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

STUDY LOAD

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Total learning time: 187.5 h

CONTENTS

Models of Population Dynamics

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

Full-or-part-time: 37h 30m
Theory classes: 6h
Laboratory classes: 6h
Self study: 25h 30m

Mathematical Models in Neurophysiology

Description:
1. Membrane biophysics.
2. Excitability and action potentials: the Hodgkin-Huxley model, the Morris-Lecar model, integrate & fire models.
4. Synaptic transmission and dynamics.

Full-or-part-time: 56h 15m
Theory classes: 9h
Laboratory classes: 9h
Self study: 38h 15m
Biological networks

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

**Full-or-part-time:** 18h 45m
- Theory classes: 3h
- Laboratory classes: 3h
- Self study: 12h 45m

Mathematical models in Genomics

**Description:**
1. Brief introduction to genomics and phylogenetics (genome, gen structure, alignments, evolution of species...). Retrieving genomic sequences and alignments.
2. Markov models of molecular evolution (Jukes-Cantor, Kimura, Felsenstein hierarchy...), phylogenetic trees, branch lengths.

**Full-or-part-time:** 75h
- Theory classes: 12h
- Laboratory classes: 12h
- Self study: 51h

GRADING 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.

BIBLIOGRAPHY

**Basic:**

**Complementary:**


Course guides
34951 - NCA - Non-Commutative Algebra

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER
Coordinating lecturer: JOSE BURILLO PUIG
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 and 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.
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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
Classes follow the traditional structure of lecture by the professor, together with the assignment of problems and exercises for the students to solve and present, either in written or in oral form.
**LEARNING OBJECTIVES OF THE SUBJECT**

The main goal is to introduce the student into the basic ideas and techniques of non-commutative algebra, to the extend of being able to enroll himself/herself 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 modern mathematics and students of any degree in mathematics have been introduced to it. The main goal of the present topic is to go a bit deeper into this area of mathematics, offering 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**

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**Total learning time:** 187.5 h

**CONTENTS**

**Generalities about infinite groups**

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

**Full-or-part-time:** 45h
Theory classes: 15h
Self study : 30h

**Cayley graphs and growth of groups**

**Description:**
Cayley graph and growth of a group
Quasi-isometries, geometric properties
Growth of groups: polynomial, intermediate, exponential, uniformly exponential
Gromow theorem

**Full-or-part-time:** 45h
Theory classes: 15h
Self study : 30h
### Hyperbolic groups

**Description:**
- Several definitions of hyperbolicity for groups
- Hyperbolic groups admit a Dehn presentation
- Centralizers in hyperbolic groups
- Characterization of hyperbolic groups as those having linear Dehn function

**Full-or-part-time:** 45h
- Theory classes: 15h
- Self study: 30h

### Algorithmic problems in groups

**Description:**
- The three classical algorithmic problems in group theory: word, conjugacy and isomorphism problems.
- Resolution in simple cases: abelian, free, free-like constructions, residually finite, etc.
- Tietze transformations, an attack to the isomorphism problem
- Some unsolvability results: Novikov, Miller, Mihailova, etc.

**Full-or-part-time:** 45h
- Theory classes: 15h
- Self study: 30h

### GRADING SYSTEM

Students will have to present in written and/or oral form the exercises assigned along the development of the course.

At the end of the course, each student (individually or in small groups) will choose a topic in Geometric Group Theory of his/her interest (from an offered list, or proposed by himself/herself and validated by the teacher), and write a project on it, preparing both a written document (15-20 pages) and a one-two hours lecture on it.

### BIBLIOGRAPHY

**Basic:**

**Complementary:**

### RESOURCES

**Other resources:**
Several interesting papers and notes by Chuck Miller:

https://researchers.ms.unimelb.edu.au/cfm/papers
Course guides
34953 - NT - Number Theory

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).
Academic year: 2020 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: ANA RIO DOVAL
Others:
Primer quadrimestre:
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.
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8. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

TEACHING METHODOLOGY

Most of the lectures will take place on the blackboard (replaced by online lessons if necessary), 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) Number theory in function fields.
3) Cyclotomic theory.

STUDY LOAD

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Total learning time: 187.5 h

CONTENTS

Algebraic Number Theory

Description:
Introduction
Cyclotomic extensions
Cyclotomic polynomials

Full-or-part-time: 10h
Theory classes: 10h

Number Theory in function fields

Description:
Functions fields over finite fields
Carlitz polynomials
Carlitz extensions

Full-or-part-time: 10h
Theory classes: 10h
Cyclotomic Theory

Description:
Cyclotomic integers
Cyclotomic units
Unique factorization
Class numbers
Galois action
Kronecker-Weber theorem
Regular polygons
Fermat equation
Quadratic reciprocity
Carlitz modules
Galois action
Carlitz-Hayes theorem
Cyclotomic and Carlitz analogies
Quadratic reciprocity
Drinfeld modules

Full-or-part-time: 40h
Theory classes: 40h

GRADING 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.

EXAMINATION RULES.

Solved exercises and works must be delivered according to schedule.

BIBLIOGRAPHY

Basic:

RESOURCES

Computer material:
- SAGE. Mathematical Software
- Matlab. Mathematical software
Course guides
34964 - NMDS - Numerical Methods for Dynamical Systems

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).

Academic year: 2020   ECTS Credits: 7.5   Languages: English

LECTURER

Coordinating lecturer: 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:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
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TEACHING METHODOLOGY

Theoretical sessions (presence of the students is necessary) and weekly practical tutorized assignments.
LEARNING OBJECTIVES OF THE SUBJECT

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

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CONTENTS

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

Full-or-part-time: 4h
Theory classes: 2h
Practical classes: 2h


Full-or-part-time: 6h
Theory classes: 3h
Practical classes: 3h


Full-or-part-time: 10h
Theory classes: 5h
Practical classes: 5h

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

Full-or-part-time: 15h
Theory classes: 7h 30m
Practical classes: 7h 30m

Analysis of bifurcations. Some examples.

Full-or-part-time: 15h
Theory classes: 7h 30m
Practical classes: 7h 30m
GRADING SYSTEM

65% of the qualification will be obtained from the practical assignments done and 35% from short exams.

EXAMINATION RULES.

No rules, in principle.

BIBLIOGRAPHY

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

Unit in charge: School of Mathematics and Statistics
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2020  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: 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.
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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 recalls the theoretical basis of the Finite Element Method (FEM) for the solution of elliptic and parabolic equations, an introduction to stabilization techniques for convection-dominated problems and the FEM for compressible flow problems, and for wave problems with application to bounded and unbounded domains.

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.

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CONTENTS

Fundamentals of Finite Element Methods (FEM)

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

Full-or-part-time: 28h
Theory classes: 14h
Laboratory classes: 14h

FEM for incompressible flow problems

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

Full-or-part-time: 16h
Theory classes: 8h
Practical classes: 8h
FEM for wave problems

Description:
FEM solution of the 1D wave equation. FEM solution of Helmholtz equation. Non-reflecting boundary conditions. Application to acoustics.
Introduction to DG for first order conservation laws. Application to acoustics and electromagnetics.

Full-or-part-time: 16h
Theory classes: 8h
Laboratory classes: 8h

GRADING SYSTEM

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

BIBLIOGRAPHY

Basic:

Complementary:
Course guides
34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

LECTURER

Coordinating lecturer: PAU MARTIN DE LA TORRE

Others:
Primer quadrimestre:
INMACULADA CONCEPCION BALDOMA BARRACA - A
PAU MARTIN DE LA TORRE - A

PRIOR SKILLS

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

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
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7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
TEACHING METHODOLOGY

We 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 perturbative techniques to study a dynamical system globally.

LEARNING OBJECTIVES OF THE SUBJECT

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>127.5</td>
<td>68.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>60.0</td>
<td>32.00</td>
</tr>
</tbody>
</table>

Total learning time: 187.5 h

CONTENTS

Invariant objects in Dynamical Systems

Description:

Full-or-part-time: 10h
Theory classes: 10h

Normal forms

Description:
Poincaré-Dulac normal forms. Convergence: Poincaré and Siegel domains.

Full-or-part-time: 10h
Theory classes: 10h

Perturbation theory in Dynamical Systems

Description:

Full-or-part-time: 15h
Theory classes: 15h
**Bifurcations**

**Description:**
Local bifurcations for planar vector fields and real maps. Saddle node and Hopf bifurcations.

**Full-or-part-time:** 10h
Theory classes: 10h

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**Homoclinic points and chaotic Dynamics**

**Description:**

**Full-or-part-time:** 10h
Theory classes: 10h

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**Non-smooth systems**

**Description:**
Introduction to non-smooth differential equations. Definition and motivating examples. Filippov's convention.

**Full-or-part-time:** 5h
Theory classes: 5h

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**GRADING 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.

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**EXAMINATION RULES.**

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

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**BIBLIOGRAPHY**

**Basic:**
Course guides
200901 - SAGDM - Seminar on Algebra, Geometry and Discrete Mathematics

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).
Academic year: 2020 ECTS Credits: 3.0 Languages: English

LECTURER
Coordinating lecturer: JUAN JOSÉ RUE PERNA

PRIOR SKILLS
The student must know the basics on graph theory. Additionally, it is necessary to have some knowledge on probability theory, group theory and arithmetics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES
Specific:
MAMME-CE1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
MAMME-CE3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

TEACHING METHODOLOGY
This seminar will be based on the presentation (from the responsible and the students) of material in the context of the theory of expanders. This material will be taken from specialized books and research papers.

LEARNING OBJECTIVES OF THE SUBJECT
The main objective of the seminar is to show an area of mathematics that intersects both algebra and geometry, discrete mathematics and other related areas, such as computer science, low-dimensional geometry and probability theory, among others.

The main objective is to get the student to gain a basic knowledge of expander theory, as well as the various applications in various branches of contemporary mathematics. In this direction, the student will also be encouraged to learn to conduct technical talks in public and in the preparation of technical scientific documents.
STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>51,0</td>
<td>68.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>24,0</td>
<td>32.00</td>
</tr>
</tbody>
</table>

Total learning time: 75 h

CONTENTS

Spectral graph Theory and expanders

Description:
- Spectral graph theory.

Full-or-part-time: 20h
Theory classes: 6h 40m
Self study : 13h 20m

Graph expanders and group theory

Description:
- Cayley graphs. Properties
- Random walks in Cayley graphs.
- Kazhan Property (T) and relation with expansion phenomena

Full-or-part-time: 9h 20m
Theory classes: 6h
Self study : 3h 20m

Graf expanders and Number Theory

Description:
- Classical algebraic groups and quasi-random groups.
- Expansion in SL2(Fq): Helfgott Theorem and Bourgain-Gamburd

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h
Other applications of graph expanders

Description:
- Applications in knot theory: the Barzdin-Kolmogorov theorem
- Applications in theoretical computer science: design of concentrators
- Applications in theoretical computing: design of algorithms
- Applications in algebraic number theory: elliptic curves

Full-or-part-time: 12h
Theory classes: 6h
Self study: 6h

GRADING SYSTEM

The grading of this seminar will be based on three points: (CA) Continuous evaluation, (MP) Material preparation and (PT) presentation.

(CA): will be based on the understanding of the material, as well as the meetings that will be held between the student and the responsible to prepare the student's presentation (or presentations). It will also include the fact of being active during the seminar sessions.

(MP): preparation of both the presentation, its good preparation and the summary sheet.

(PT): presentation. This will include questions from the teacher and students.

Overall grading of the seminar: 30% (CA)+20% (MP)+50% (PT)

BIBLIOGRAPHY

Basic:

Complementary:
Course guides  
**200902 - SADEM - Seminar on Analysis, Differential Equations and Modelling**

**Unit in charge:** School of Mathematics and Statistics  
**Teaching unit:** 749 - MAT - Department of Mathematics.  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).  
**Academic year:** 2020  
**ECTS Credits:** 3.0  
**Languages:** English

**LECTURER**

*Coordinating lecturer:* GEMMA HUGUET CASADES  
*Others:* Segon quadrimestre:  
GEMMA HUGUET CASADES - A  
JOSE JAVIER MUÑOZ ROMERO - A

**PRIOR SKILLS**

It is important to have some background in one of the following areas: Dynamical Systems, Partial Differential Equations, Numerical methods and discretisation methods for PDEs.

**DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES**

**Specific:**
MAMME-CE1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.  
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.  
MAMME-CE3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.  
MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

**TEACHING METHODOLOGY**

Students will present a topic related to Mathematical Analysis for Oscillatory Systems autonomously on a seminar format. This material will be taken from specialized books and research papers. There will be some meetings between the instructor and the students before the oral presentation. Students must prepare an abstract of the seminar to help the rest of the students attending the seminar to understand the topic. Students must attend at least 90% of the lectures and be active in all the presentations.

**LEARNING OBJECTIVES OF THE SUBJECT**

The main goal is to provide the students with a basic knowledge on the mathematical analysis for oscillatory systems, as well as, several applications in different branches of applied mathematics. The topic intersects with dynamical systems, partial differential equations as well as numerical methods, amongst others.

Additionally, the students will learn how to conduct technical talks in public and prepare technical scientific documents.
STUDY LOAD

<table>
<thead>
<tr>
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<tr>
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<tr>
<td>Self study</td>
<td>51,0</td>
<td>68.00</td>
</tr>
</tbody>
</table>

Total learning time: 75 h

CONTENTS

**Mathematical tools for periodic orbits and stability analysis**

**Description:**
Poincaré Section. Perturbation analysis. Characteristic equations

**Full-or-part-time:** 15h
- Theory classes: 4h
- Self study: 11h

**Biological oscillators**

**Description:**

**Full-or-part-time:** 30h
- Theory classes: 10h
- Self study: 20h

**Oscillations in mechanics**

**Description:**

**Full-or-part-time:** 30h
- Theory classes: 10h
- Self study: 20h

GRADING SYSTEM

The grading of this seminar will be based on three aspects: (C) Continuous evaluation, (M) Material preparation and (P) Presentation.

(C): the grade will be based on the understanding of the material, as well as the meetings that will be held between the student and the instructor to prepare the student’s presentation (or presentations). The goal of the seminar is to ensure that the audience understands the lectures and its technicalities.

(M): the grade will be based on the quality of both the presentation slides and the abstract.

(P): the grade will be based on the clarity of the presentation. This will include questions from the teacher and students.

Overall grading of the seminar: 30% (C) + 20% (M) + 50% (P)
**BIBLIOGRAPHY**

**Basic:**