Study Guide

23/24

Faculty of Mathematics and Statistics

Master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Facultat de Matemàtiques i Estadística
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  - Focus on Partial Differential Equations and Analysis
  - Focus on Mathematical and Computational Modelling with PDEs
  - Focus on Optimization and Operation Research for Efficient Decision Making
  - Focus on Modelling and Analysis in Biomedical Sciences
  - Focus on Algebra, Geometry and Number Theory
  - Focus on Dynamical Systems and Applications to Celestial Mechanics
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Master's degree in Advanced Mathematics and Mathematical Engineering (MAMME)

The master's degree in Advanced Mathematics and Mathematical Engineering (MAMME) is a master's programme in mathematics offered at the School of Mathematics and Statistics (FME).

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

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

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, €1,660 (€4,150 for non-EU residents).
More information about fees and payment options
More information about grants and loans

Language of instruction
English
Information on language use in the classroom and students' language rights.

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**

33

**Pre-enrolment**

Pre-enrolment period open.

Expected deadline: 30/11/2022.

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's degree 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 competencies**

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**

**UPC school**
- School of Mathematics and Statistics (FME)

**Academic coordinator**
- Juan José Rue Perna

**Academic calendar**
- General academic calendar for bachelor's, master's and doctoral degrees courses

**Academic regulations**
- Academic regulations for master's degree courses at the UPC

### CURRICULUM

<table>
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<th>Subjects</th>
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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) (web del màster) 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.


DADES GENERALS

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

Horaris i modalitat
Tarda. Presencial

Preus i beques
Preu aproximat del màster sense altres despeses addicionals (no inclou taxes acadèmiques de caràcter no docent ni expedició del títol):
1.660 € (4.150 € per a no residents a la UE).
Més informació sobre preus i pagament de la matrícula
Més informació de beques i ajuts

Idiomes
Anglès
Informació sobre l'ús de llengües a l'aula i els drets lingüístics de l'estudiantat.

Lloc d'impartició
Facultat de Matemàtiques i Estadística (FME)

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

ACCÉS

Requisits generals
Requisits acadèmics d’accés a un màster

Places
30 places setembre i 3 places al febrer

Preinscripció
Període de preinscripció obert.
Com es formalitza la preinscripció?

Admissió i matrícula
Com es formalitza la matrícula?

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.**

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 (ITT), Chicago, USA). (Flux solament de l’FME a Illinois)
- Master's degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Industrial and Applied Mathematics (MSIAM) (Institute d'Ingénerie et de Management, Université Grenoble Alpes (UGA), Grenoble, França)

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.

ORGANITZACIÓ ACADÈMICA: NORMATIVES, CALENDARIS

Centre docent UPC
Facultat de Matemàtiques i Estadística (FME)

Responsable acadèmic del programa
Jordi Saludes Closa

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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<th>crèdits ECTS</th>
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<td>Modelització Matemàtica amb Equacions en Derivades Parcials</td>
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<td>Sistemes Hamiltonians</td>
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Novembre 2023. 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) (web del máster) es un programa de máster ofrecido por la Facultad de Matemáticas y Estadística (FME) de 60 ECTS, divididos en 45 ECTS de cursos, más 15 ECTS de tesis de máster.

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

Además, MAMME ofrece la posibilidad de cursar hasta 22.5 ECTS en otros másteres en matemáticas o estadística, o en otros másteres de la UPC, permitiendo diseñar un currículum interdisciplinar basado en la selección de cursos en másteres en ingeniería o ciencias aplicadas. Vea las propuestas de focalización en http://mamme.masters.upc.edu/en.

DATOS GENERALES

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<th>Duración e inicio</th>
<th>Un curso académico, 60 créditos ECTS. Inicio septiembre y febrero</th>
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</thead>
<tbody>
<tr>
<td>Horarios y modalidad</td>
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</table>
| Precios y becas | Precio aproximado del máster sin otros gastos adicionales (no incluye tasas académicas de carácter no docente ni expedición del título): 1.660 € (4.150 € para no residentes en la UE). Más información sobre precios y pago de la matrícula
Más información de becas y ayudas |
| Idiomas | Inglés |
| Información sobre el uso de lenguas en el aula y los derechos lingüísticos de los estudiantes. |
| Lugar de impartición | Facultad de Matemáticas y Estadística (FME) |
| Título oficial | Inscrito en el registro del Ministerio de Educación, Cultura y Deporte |

ACCESO

Requisitos generales
Requisitos académicos de acceso a un máster
Plazas
33
Preinscripción
Periodo de preinscripción abierto.
¿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's degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Applied Mathematics (Illinois Institute of Technology (ITT), Chicago, USA). (Flujo sólo de la FME en Illinois)
- Master's degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Industrial and Applied Mathematics (MSIAM) (Institute d'Ingénerie et de Management, Université Grenoble Alpes (UGA), Grenoble, Francia)

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
Jordi Saludes Closa

Calendario académico
Calendario académico de los estudios universitarios de la UPC

Normativas académicas
## PLAN DE ESTUDIOS

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Study program

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

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

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

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

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

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

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

MAMME courses are offered in five broad fields: Algebra and Geometry, Discrete Mathematics and Algorithmics, Modelling in Engineering and Biomedical Sciences, Differential Equations, and Scientific Computing.

The following courses (7.5 ECTS each) are offered.

Field: Algebra and Geometry

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

Field: Discrete Mathematics and Algorithmics

- **Codes and Cryptography** (Spring term Q2)
- **Combinatorics** (Spring term Q2)
- **Discrete and Algorithmic Geometry** (Spring term Q1)
- **Graph Theory** (Spring term Q1)

Field: Modelling in Engineering and Biomedical Sciences

- **Mathematical Modelling with Partial Differential Equations** (Spring term Q1)
- **Computational Mechanics** (Spring term Q2)
- **Mathematical Models in Biology** (Spring term Q1)

Field: Differential Equations

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

Field: Scientific Computing

- **Numerical Methods for Dynamical Systems** (Spring term Q1)
- **Numerical Methods for Partial Differential Equations** (Spring term Q2)
- **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)
Focus Proposals

The following is a NON-EXHAUSTIVE list of focus proposals that may be considered for the selection of courses in MAMME, including both MAMME courses and courses in other master programs. They are just examples for selection of courses, and they will not be mentioned in the master's degree certificate. Students are encouraged to design their own curriculum with total freedom.

In any case, recall that a minimum of 22.5 ECTS in MAMME courses is mandatory. Registration in non-MAMME courses requires the approval of the director of MAMME and of the director of the other master.

---

Discrete Mathematics

Partial Differential Equations and Analysis

Mathematical and Computational Modelling

Optimization and Operation Research

Dynamical Systems and Applications to Celestial Mechanics

Algebra, Geometry and Number Theory
Focus on Discrete Mathematics

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

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

Random graphs, the basic model for random structures  
Triangulations, a basic tool for computational geometry  
Cryptography, one of the key applications of discrete mathematics

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

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

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

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

Partial Differential Equations (PDEs) play a central role in physics, chemistry, biology, industry, mathematical finance, and image processing. Their analysis often requires deep mathematical techniques, which makes PDEs 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.

Pattern formation with reaction-diffusion systems of PDEs
Free boundaries and PDEs: the Stefan problem for melting ice
Lévy flights and PDEs in finance, biological invasions...

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

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced course in PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical Modeling with PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Stochastic Calculus</td>
<td>6</td>
<td>English</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Complex Analysis</td>
<td>6</td>
<td>English</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

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

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

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

Students interested in focusing on 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>Course Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical Modelling with PDEs</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Computational Mechanics</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced Course in PDEs</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced Fluid Mechanics**</td>
<td>5 ECTS</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Finite Elements in Fluids**</td>
<td>5 ECTS</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Advanced Discretization Methods**</td>
<td>5 ECTS</td>
<td>English</td>
<td>Master in Numerical Methods in Engineering, UPC</td>
</tr>
<tr>
<td>Numerical Modelling*</td>
<td>9 ECTS</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.
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).

![Map of a city]

Travelling salesman problem solution  Traffic simulation system

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

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

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

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

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

Brain dynamics: modelling and analysis at different levels, with different tools (differential equations, graphs, statistics,...)  
Simulation of curved cellular monolayers with computational mechanics
<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Master's 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>Numerical Modeling*</td>
<td>9</td>
<td>English</td>
<td>Máster en Enginyeria de Camins, Canals i Ports, UPC</td>
</tr>
<tr>
<td>Técnicas básicas en neurociencia**</td>
<td>5</td>
<td>English</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Biología Celular y Molecular de la Neurona**</td>
<td>5</td>
<td>English</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Diseño y análisis de datos en neurociencia cognitive**</td>
<td>2.5</td>
<td>English</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Neurociencia computacional**</td>
<td>2.5</td>
<td>English</td>
<td>Máster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
</tbody>
</table>

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

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

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

Mathematics departments at UPC gather several research groups specialized in Number Theory, Algebraic Geometry, Differential Geometry and commutative and non-commutative Algebra. All of them collaborate closely with other researchers of the Universitat de Barcelona and the Universitat Autònoma de Barcelona, and with research groups of some of the most prestigious universities around the world. Many young researchers began their scientific careers by coursing the Master and/or doing the PhD in one of the UPC groups: Ariadna, Biel, Carlos, Enrique, Francesc, Francesc, Marc, Maria, Martí, Pere-Daniel, Santí, Victor, 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>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commutative Algebra*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Non-Commutative Algebra*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Differentiable Manifolds*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Number Theory*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Algebraic Geometry*</td>
<td>MAMME</td>
</tr>
<tr>
<td>Geometry and Topology of Varieties</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Algebraic Curves**</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Computational Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Geometrical Methods in Number Theory</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Local Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

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

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

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

Dynamical Systems provide a powerful mathematical background to explore a great variety of models involving natural and social sciences, physics, chemistry, ecology, econometrics, 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>ECTS</th>
<th>Language</th>
<th>Course Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative and quantitative methods in dynamical systems</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>Hamiltonian systems</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical models in biology</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Advanced course in partial differential equations</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Dynamical systems</td>
<td>6</td>
<td>English</td>
<td>Master's degree in advanced and professional mathematics (UB)</td>
</tr>
<tr>
<td>Simulation methods</td>
<td>6</td>
<td>English</td>
<td>Master's degree in advanced and professional mathematics (UB)</td>
</tr>
</tbody>
</table>
Focus on Geometry and its applications

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

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commutative Algebra</td>
<td>7</td>
<td>MAMME</td>
</tr>
<tr>
<td>Non-Commutative Algebra</td>
<td>7</td>
<td>MAMME</td>
</tr>
<tr>
<td>Differentiable Manifolds</td>
<td>7</td>
<td>MAMME</td>
</tr>
<tr>
<td>Algebraic Geometry</td>
<td>7</td>
<td>MAMME</td>
</tr>
<tr>
<td>Geometry and Topology of Varieties</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Algebraic Curves</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Computational Algebra</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Local Algebra</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

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

Attached there is the list of double degrees in association with MAMME

MAMME-IIT (IIT, USA)

MAMME-INP Grenoble (Grenoble, France)

UPC_MoU_2226.pdf

UPC_DD_Ensimag_2226.pdf

DDUPCANnex.pdf

Mobility

MAMME offers several possibilities for mobility.

Erasmus mobility

MAMME allows mobility under the Erasmus program, usually during the Spring semester (Q2).

Students may do courses at the host institution, provided they have passed a minimum of 22.5 ECTS in MAMME courses.

There are two options for the master thesis:

1. Erasmus+ studies: only for the institutions in http://fme.upc.edu/ca/estudis/mobilitat/socrates-erasmus#erasmus. For Erasmus fellowships, eligible students must register 30 ECTS (usually 15 ECTS in courses + master thesis). You should previously check if the potential receiving institution allows the registration of the master thesis for Erasmus students.

2. Erasmus+ training: only master thesis, no courses. An agreement can be done with any institution, even when it is not appearing in the previous list.

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

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

Master thesis defence

The master thesis is defended publically and evaluated by 3 members of UPC. The usual session works as follow:

1) The defence of the master thesis done by the candidate (around 25 minutes). The defence must be done preferably in English.

2) A round of questions (around 20 minutes) from the committee.

3) A round of questions (if any) from people in the audience with a master degree.

Forthcoming defenses

A list of forthcoming presentations of master's thesis can be found at this link.
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 guide
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: 2022  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: ALBERT MAS BLESA

Others: Segon quadrimestre:
- XAVIER CABRE VILAGUT - A
- ALBERT MAS BLESA - A
- IÑIGO URTIAGA ERNETA - A

PRIOR SKILLS

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

REQUIREMENTS

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.
It is helpful an undergraduate course in Functional 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 PDE and find spectral decompositions,
- learn the modern methods to solve elliptic PDE.

STUDY LOAD

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<tr>
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<tr>
<td>Hours large group</td>
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</tr>
<tr>
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<td>127,5</td>
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</tr>
</tbody>
</table>

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

### 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

### 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

### 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 guide
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: 2022  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: MARIA ALBERICH CARRAMIÑANA

Others: Segon quadrimestre:
MARIA ALBERICH CARRAMIÑANA - A
PEDRO PASCUAL GAINZA - A

PRIOR SKILLS

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

REQUESTS

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:
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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 course consists of two distinct parts: global algebraic geometry and local algebraic geometry focusing on plane-curve singularities. The main objective of the first part 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 second part aims to give an insight into singularity theory of plane curves and a geometric theory of valuations of the ring of convergent series of two variables 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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Total learning time: 187.5 h

CONTENTS

Chapter 1: Algebraic varieties

Description:

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

Chapter 2: Projective varieties

Description:
Projective Nullstellensatz and projective varieties. Elimination theory. Examples: grassmannians.

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

Chapter 3: Maps and morphisms

Description:

Full-or-part-time: 18h
Theory classes: 8h
Self study: 10h
### Chapter 4: 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 5: Parametrizing branches of plane curves

**Description:**
Newton-Puiseux algorithm, Weierstrass preparation and division theorems, intersection multiplicity.

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

---

### Chapter 6: Infinitely near points

**Description:**
Proximity, Enriques diagrams, rings in successive neighbourhoods.

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

---

### Chapter 7: Topological and analytic classification of plane curves

**Description:**
Equisingularity, semigroup of values, Milnor and Tjurina numbers and other invariants.

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

---

### Chapter 8: Valuations and complete ideals

**Description:**
Classification of valuations, Zariski decomposition of complete ideals.

**Full-or-part-time:** 18h  
Theory classes: 8h  
Self study: 10h
Chapter 9: Final projects

Description:
The final works of the subject on the topics chosen by the students will be presented by the students themselves and commented by the course lecturers.

Full-or-part-time: 24h
  Theory classes: 4h
  Self study: 20h

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:
Course guide
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: 2022  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: SIMEON MICHAEL BALL MARKS

Others: Segon quadrimestre:
SIMEON MICHAEL BALL MARKS - 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.
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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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TEACHING METHODOLOGY

The course is divided in two parts: codes and cryptography. Each part consists of 26 h of ordinary classes, including theory and problem sessions.
LEARNING OBJECTIVES OF THE SUBJECT

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

STUDY LOAD

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</tr>
<tr>
<td>Hours large group</td>
<td>60.0</td>
<td>32.00</td>
</tr>
</tbody>
</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:**
Cyclic codes. Generator and control matrices. Factorization of \( x^n-1 \). Roots of a cyclic code. BCH codes. Primitive Reed-Solomon codes. Meggit's decoder.

**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 guide
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: 2022  
ECTS Credits: 7.5  
Languages: English

LECTURER

Coordinating lecturer: JUAN JOSÉ RUE PERNA

Others: Segon quadrimestre:
PATRICK MORRIS - 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.
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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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<tbody>
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</table>

**Total learning time:** 187.5 h

CONTENTS

**Partially ordered sets**

**Description:**
- Sperner's theorem.
- LYM inequalities.
- Bollobás's theorem.
- Erdos-Ko-Rado Theorem.
- Dilworth's theorem.
- Applications of Dilworth Theorem.
- Lattices and distributive lattices.
- The 4 functions theorem and applications.

**Full-or-part-time:** 24h 40m
- Practical classes: 4h
- Laboratory classes: 4h
- Self study: 16h 40m

**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

**Probabilistic methods in combinatorics**

**Description:**
- First and second moment.
- Lovász Local Lemma and entropy methods.
- Applications: 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

**Linear algebra methods in combinatorics**

**Description:**
- The polynomial method and applications.
- Fisher's theorem.

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

Continuous evaluation will be based on the weekly solution of exercises. There will be also a final examination. The grading will be based on the continuous evaluation during the course (60%) and the final exam (40%).

BIBLIOGRAPHY

Basic:
Course guide
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: 2022 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: JOSEP ALVAREZ MONTANER
Others: Primer quadrimestre:
JOSEP ALVAREZ MONTANER - A

PRIOR SKILLS

Linear algebra, algebraic structures, topology.

REQUIREMENTS

The two first years of a degree in mathematics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

Transversal:
4. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
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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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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:
60% Resolution of assigned exercises and/or projects
40% Final Exam

BIBLIOGRAPHY

Basic:
Course guide
34959 - CM - Computational Mechanics

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
751 - DECA - Department of Civil and Environmental Engineering.
748 - FIS - Department of Physics.

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

Academic year: 2022  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: JOSE JAVIER MUÑOZ ROMERO

Others: Segon quadrimestre:
ALVARO MESEGUER SERRANO - A
JOSE JAVIER MUÑOZ ROMERO - A
ANTONIO RODRIGUEZ FERRAN - 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.
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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

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 (tensors) and differential operators used in computational mechanics
- Be aware of the different level of complexity of various problems (e.g. linear vs. nonlinear, static vs. dynamic).

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
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</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

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, FRACTURE 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 guide
34966 - VD - Differentiable Manifolds

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: 2022    ECTS Credits: 7.5    Languages: English

LECTURER
Coordinating lecturer: EVA MIRANDA GALCERÀN
Others: Segon quadrimestre:
        PAU MIR GARCÍA - A
        EVA MIRANDA GALCERÀN - 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:
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. 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

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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 40% and an essay that will contribute to the final grade in another 40%. Students would choose, together with the lecturers, a topic that complements or advances the material taught during the course, according to their mathematical interests. The remaining 20% is reserved to problem solving which can be evaluated by simply solving some assignments of the regular list of problems.

EXAMINATION RULES.

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

40% exam(s) + 40% essay+ 20% problem solving

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 presentential 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-gdYzg2ghw?view_as=subscriber
Course on youtube by Professor Eva Miranda on Symplectic and Poisson Geometry
https://www.youtube.com/channel/UC8Fzyf58s0EiZ-gdYzg2ghw?view_as=subscriber
Course guide
34956 - DG - Discrete and Algorithmic 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: 2022  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: CLEMENS HUEMER
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. 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

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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<tbody>
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<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

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

### Topological Data Analysis
**Description:**
Homology: Simplicial homology, cell complexes. 
Persistent homology: persistent Betti numbers, barcodes 
Discrete Morse Theory: simplicial collapses, acyclic matchings, critical cells

**Applications**

**Full-or-part-time:** 48h  
Theory classes: 12h  
Laboratory classes: 4h  
Self study: 32h
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 guide
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: 2022  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: GUILLEM PERARNAU LLOBET
Others: Primer quadrimestre: GUILLEM PERARNAU LLOBET - A ORIOL SERRA ALBO - A

PRIOR SKILLS
Elementary Calculus and Linear Algebra; basic notions and skills 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. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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TEACHING METHODOLOGY
Combination of theoretical lectures and exercise classes, with student presenting their solutions to the proposed problems. The active participation of students is a requirement for the course assessment.
LEARNING OBJECTIVES OF THE SUBJECT

Basics of Graph Theory.
Graphs on surfaces and minors.
Random graphs.
Applications of random graphs: the probabilistic method.
Spectral techniques to the study of graphs.
Applications of spectral techniques: expansion and random walks.

STUDY LOAD

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</table>

Total learning time: 187.5 h

CONTENTS

Spectral graph theory

Description:
Introduction to spectral graph theory, graph expanders and applications to random walks on graphs.

Specific objectives:

Related competencies:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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.
07 AAT. 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.
04 COE. 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.
03 TLG. 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.
05 TEQ. 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.
06 URI. 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.

Full-or-part-time: 16h
Theory classes: 16h
Minors and treewidth

Description:
Introduction to structural graph theory.

Specific objectives:

Related competencies:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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.

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06 URI. 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.

Full-or-part-time: 8h
Theory classes: 8h
Graphs on surfaces

Description:
Introduction to planar graphs and graphs embedded in other surfaces.

Specific objectives:

Related competencies:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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.
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06 URI. 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.

Full-or-part-time: 4h
Theory classes: 4h
Random graphs

Description:
Introduction to classical model of random graphs and its main combinatorial properties.

Specific objectives:
Erdos-Rényi model of random graphs.
Properties of almost all graphs.
First and second moment methods.
The probabilistic method.
Threshold functions.
Method of Moments
Chernoff's inequality
Component phase transitions

Related competencies:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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.
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06 URI. 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.

Full-or-part-time: 12h
Theory classes: 12h
An introduction to Graph Theory

Description:
Introduction to random graphs, main properties and classical theorems.

Specific objectives:
Basic terminology and notation
Paths and cycles
Distance and Diameter
Connectivity
Trees
Matchings
Colorings

Related competencies:
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
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.

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06 URI. 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.

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

GRADING SYSTEM

The assessment of the course is as follows:
- weekly work on the proposed problems and their presentation during the lectures, 30% of the mark
- a final comprehensive exam on the course topics, 70% of the mark

EXAMINATION RULES.

The active participation in the course is a requirement for the final assessment.
BIBLIOGRAPHY

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

Complementary:
Course guide
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: 2022
ECTS Credits: 7.5
Languages: English

LECTURER
Coordinating lecturer: PAU MARTIN DE LA TORRE
Others: Segon quadrimestre:
AMADEV DELSHAMS I VALDES - A
PAU MARTIN DE LA TORRE - 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.
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8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

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

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

<table>
<thead>
<tr>
<th>Type</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>60.0</td>
<td>32.00</td>
</tr>
<tr>
<td>Self study</td>
<td>127.5</td>
<td>68.00</td>
</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
Quasi-integrable Hamiltonian systems

Description:

Full-or-part-time: 26h
Theory classes: 8h
Self study: 18h

Lagrangian systems and variational methods

Description:

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

Hamiltonian Partial Differential Equations

Description:

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

- Interactions between Dynamical Systems and Partial Differential Equations

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

Full-or-part-time: 49h 30m
Theory classes: 12h
Self study: 37h 30m

ACTIVITIES

JISD summer school

Description:
Attendance to the JISD summer school

Specific objectives:
To learn from outstanding researchers a view of the state of the art in several research topics, interacting with students of the rest of Spain and of the World.
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%). 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 guide
200900 - ML - Machine Learning

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).
MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Optional subject).
Academic year: 2022  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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<thead>
<tr>
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</tr>
</tbody>
</table>

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
<table>
<thead>
<tr>
<th>Course Title</th>
<th>Description</th>
<th>Full-or-part-time</th>
<th>Theory classes</th>
<th>Practical classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>General introduction to machine learning</td>
<td>Introduction to Bayesian thinking for machine learning. Learning by solving a regularized problem. Illustrative example.</td>
<td>5h</td>
<td>2h</td>
<td>3h</td>
</tr>
<tr>
<td>Learning in functional spaces</td>
<td>Reproducing kernel Hilbert spaces. The representer theorem. Example 1: Kernel ridge regression. Example 2: The Perceptron and the kernel Perceptron.</td>
<td>8h</td>
<td>4h</td>
<td>4h</td>
</tr>
<tr>
<td>Kernel functions in $\mathbb{R}^d$</td>
<td>Description and demonstration of fundamental kernel functions in $\mathbb{R}^d$. Polynomial and Gaussian kernels. General properties of kernel functions.</td>
<td>4h</td>
<td>2h</td>
<td>2h</td>
</tr>
<tr>
<td>The support vector machine for classification, regression and novelty detection</td>
<td>The support vector machine (SVM) is the flagship in kernel methods. Its versions for classification, regression and novelty detection are explained and demonstrated.</td>
<td>6h</td>
<td>4h</td>
<td>2h</td>
</tr>
<tr>
<td>Kernel functions for different data types</td>
<td>Some kernel functions for different data types are presented and demonstrated, such as text, trees, graphs, categorical variables, and others.</td>
<td>6h</td>
<td>4h</td>
<td>2h</td>
</tr>
</tbody>
</table>
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:**
- Hastie, Trevor; Tibshirani, Robert; Wainwright, Martin. Statistical learning with sparsity : The Lasso and Generalizations [on line]. CRC r at o n, 2015 [ C o n s u l t a t i o n : 3 0 / 0 6 / 2 0 2 0]. A v a i l a b l e o n: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=4087701. ISBN 78-1-4987-1216.

**Complementary:**
- Smola, Alexander J. Advances in large margin classifiers [on line]. Cambridge, Mass.: MIT Press, 2000 [Consultation: 13/07/2022]. A v a i l a b l e o n:
Course guide
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
751 - DECA - Department of Civil and Environmental Engineering.

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

Academic year: 2022  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: SONIA FERNANDEZ MENDEZ

Others: Primer quadrimestre:
JEZABEL CURBELO HERNANDEZ - A
SONIA FERNANDEZ MENDEZ - A
JAIME HARO CASES - A
JOSE JAVIER MUÑOZ ROMERO - A

PRIOR SKILLS

Good knowledge of Calculus techniques, including integral theorems. Elementary solution of PDEs and ODEs.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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

TEACHING METHODOLOGY

The course mainly consists of theoretical lectures, but it also includes problem solving and computer sessions, with given finite differences codes to illustrate the behaviour of the models.
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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</table>

Total learning time: 187.5 h

CONTENTS

1 Heat conduction and diffusion

Description:
Review of Vector Calculus, Fick and Fourier laws, random walks, self-similar solutions. Boundary conditions, energy functionals.

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

2 Potentials in physics and technology

Description:
Classical gravitation. Electrostatics.

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

3 Transients in continuous media

Description:

Full-or-part-time: 20h
Theory classes: 20h

4. Fluid Mechanics

Description:

Full-or-part-time: 20h
Theory classes: 20h
GRADING SYSTEM

60% continuous assessment (assignments and exercises) and 40% exam.

BIBLIOGRAPHY

Basic:

Complementary:
Course guide
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: 2022
ECTS Credits: 7.5
Languages: English

LECTURER
Coordinating lecturer: GEMMA HUGUET CASADES
Others: Primer quadrimestre:
JESUS FERNANDEZ SANCHEZ - A
GEMMA HUGUET CASADES - 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.
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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 be 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

Mathematical models in phylogenetics

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
Mathematical Models in Neuroscience

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.
6. Applications to cognitive tasks (working memory, decision making and visual perception).
7. Recurrent Neural Networks.

Full-or-part-time: 100h
Theory classes: 16h
Laboratory classes: 16h
Self study : 68h

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: 12h 30m
Theory classes: 2h
Laboratory classes: 2h
Self study : 8h 30m

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:
- Bacaër, N.; Bravo de la Parra, R.; Ripoll, J. Breve historia de los modelos matemáticos en dinámica de poblaciones [on line].
Course guide
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: 2022 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: ENRIC VENTURA CAPELL
Others: Primer quadrimestre:
JOSE BURILLO PUIG - A
JORGE DELGADO RODRÍGUEZ - 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 COMPETENECES 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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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 extent 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 guide
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: 2022  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.

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.
2) Cyclotomic theory.

STUDY LOAD

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<tr>
<td>Self study</td>
<td>127,5</td>
<td>68.00</td>
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</tbody>
</table>

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.

EXAMINATION RULES.

Solved exercises and works must be delivered according to schedule.

BIBLIOGRAPHY

Basic:

RESOURCES

Computer material:
- SAGE. Mathematical Software
- Matlab. Mathematical software
Course guide
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: 2022
ECTS Credits: 7.5
Languages: English

LECTURER

Coordinating lecturer: MERCEDES OLLE TORNER

Others:
Primer quadrimestre: 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.
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

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

STUDY LOAD

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</table>

Total learning time: 187.5 h

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

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

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

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

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 guide
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: 2022 ECTS Credits: 7.5 Languages: English

LECTORER

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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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

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.

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

STUDY LOAD

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</table>

Total learning time: 187.5 h

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.
Application to the numerical modelling of flow in porous medium, and potential flow.
Introduction to a posteriori error estimation and adaptivity.
Time integration for transient problems.
Solution of the convection-diffusion equation. Stabilized formulations for convection dominated problems.
Numerical solution of linear elasticity problems.

Full-or-part-time: 32h
Theory classes: 16h
Laboratory classes: 16h

FEM for incompressible flow problems

Description:
Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition.
Introduction to the numerical solution of the incompressible Navier-Stokes equations.

Full-or-part-time: 14h
Theory classes: 7h
Practical classes: 7h
**FEM for wave problems**

**Description:**
Introduction to DG for first order conservation laws.

**Full-or-part-time:** 14h
- Theory classes: 7h
- Laboratory classes: 7h

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**GRADING SYSTEM**

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

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**BIBLIOGRAPHY**

**Basic:**

**Complementary:**
Course guide
34961 - QQMDS - Quantitative and Qualitative Methods in 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: 2022  ECTS Credits: 7.5  Languages: English

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.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

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

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

**LEARNING OBJECTIVES OF THE SUBJECT**

**STUDY LOAD**

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Total learning time: 187.5 h

**CONTENTS**

**Invariant objects in Dynamical Systems**

**Description:**
Continuous and discrete Dynamical Systems.
Poincaré map.
Local behaviour of hyperbolic invariant objects. Conjugation.
Invariant manifolds.

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

**Normal forms**

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

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

**Perturbation theory in Dynamical Systems**

**Description:**

**Full-or-part-time:** 15h
Theoretical 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

Homoclinic points and chaotic Dynamics

Description:

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

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

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.

EXAMINATION RULES.

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

BIBLIOGRAPHY

Basic:
Course guide
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: 2022 ECTS Credits: 3.0 Languages: English

LECTURER

Coordinating lecturer: JUAN JOSÉ RUE PERNA
Others: Segon quadrimestre: JUAN JOSÉ RUE PERNA - A

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

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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:
- Davidoff,Giuliana; Sarnak, Peter; Valette, Alain. Elementary number theory, group theory and Ramanujan graphs [on line]. London Mathematical Society, 2003Available on: https://doi.org/10.1017/CBO9780511615825.

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

Unit in charge: School of Mathematics and Statistics
Teaching unit: 748 - FIS - Department of Physics.
749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).
Academic year: 2022  ECTS Credits: 3.0  Languages: English

LECTURER

Coordinating lecturer: GEMMA HUGUET CASADES
Others: Segon quadrimestre:
GEMMA HUGUET CASADES - A
JOSEP JOAQUIM MASDEMON SOLER - A
ALVARO MESEGUER SERRANO - 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/report 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 mathematical methods for the 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

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<td>24,0</td>
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</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/report.
(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:
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) (web del màster) 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 interdisciplinaries 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.


DADES GENERALS

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ACCÉS

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Admissió i matrícula
Com es formalitza la matrícula?

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.

ACORDS DE DOBLE TITULACIÓ

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

SORTIDES PROFESSIONALS

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

ORGANITZACIÓ ACADÈMICA: NORMATIVES, CALENDARIS

Centre docent UPC
Facultat de Matemàtiques i Estadística (FME)

Responsable 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
<table>
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<th>Assignatures</th>
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Octubre 2022. **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) (web del máster) 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

<table>
<thead>
<tr>
<th>Duración e inicio</th>
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<tr>
<td>Precios y becas</td>
<td>Precio aproximado del máster sin gastos adicionales, 1.660 € (4.150 € para no residentes en la UE).</td>
</tr>
<tr>
<td></td>
<td>Más información sobre precios y pago de la matrícula</td>
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<tr>
<td></td>
<td>Más información de becas y ayudas</td>
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<tr>
<td>Idiomas</td>
<td>Inglés</td>
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<tr>
<td></td>
<td>Información sobre el uso de lenguas en el aula y los derechos lingüísticos de los estudiantes.</td>
</tr>
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<td>Inscrito en el registro del Ministerio de Educación, Cultura y Deporte</td>
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### ACCESO

<table>
<thead>
<tr>
<th>Requisitos generales</th>
<th>Requisitos académicos de acceso a un máster</th>
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</thead>
<tbody>
<tr>
<td>Plazas</td>
<td>33</td>
</tr>
</tbody>
</table>
¿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

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

<table>
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<tr>
<th>Asignaturas</th>
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<td>Métodos Cuantitativos y Cualitativos en Sistemas Dinámicos</td>
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<td>Métodos Numéricos para Ecuaciones en Derivadas Parciales</td>
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<td>Mecánica Computacional</td>
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<tr>
<td>Seminario de Álgebra, Geometría y Matemática Discreta</td>
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<td>Seminario de Análisis, Ecuaciones Diferenciales y Modelización</td>
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Octubre 2022. **UPC. Universitat Politècnica de Catalunya · BarcelonaTech**
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 (does not include non-teaching academic fees and issuing of the degree certificate):
€1,660 (€4,150 for non-EU residents).
More information about fees and payment options
More information about grants and loans

Language of instruction
English

Information on language use in the classroom and students' language rights.

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

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Pre-enrolment

Pre-enrolment period open.
Expected deadline: 30/11/2023.

How to pre-enrol

Enrolment

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 (ITT), Chicago, USA). (Only FME students to Illinois, not vice versa.)
- Master's degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Industrial and Applied Mathematics (MSIAM) (Institute d'Ingénierie et de Management, Université Grenoble Alpes (UGA), Grenoble, France)

PROFESSIONAL OPPORTUNITIES

Professional opportunities

Some of the career prospects of master's degree 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 competencies

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

UPC school
School of Mathematics and Statistics (FME)

Academic coordinator
Jordi Saludes Closa

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

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

CURRICULUM

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<tr>
<th>Subject</th>
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<td>Graph Theory</td>
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November 2023. UPC. Universitat Politècnica de Catalunya · BarcelonaTech
Focus on Discrete Mathematics

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

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

Triangulations, a basic tool for computational geometry

Cryptography, one of the key applications of discrete mathematics

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

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
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<tbody>
<tr>
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<tr>
<td>Graph Theory</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Codes an Cryptography</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Discrete and Algorithmic Geometry</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
</tbody>
</table>
General information

Study program

Focus Proposals

Focus on Discrete Mathematics

Focus on Partial Differential Equations and Analysis
Focus on Mathematical and Computational Modelling with PDEs
Focus on Optimization and Operation Research for Efficient Decision Making

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

Recall that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.
Focus on Modelling and Analysis in Biomedical Sciences
Focus on Algebra, Geometry and Number Theory
Focus on Dynamical Systems and Applications to Celestial Mechanics
Focus on Geometry and its applications

Admission requirements and pre-enrolment

Double degrees

Mobility

Testimonies

Grants and student awards

Management team and location

Quality System

Master's thesis

Current academic year information

Forthcoming defenses of master's thesis
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**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:

| Commutative Algebra* | MAMME |

https://mamme.masters.upc.edu/en/focus-proposals/focus-on-algebra-geometry-and-number-theory
<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Non-Commutative Algebra*</td>
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</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>
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<tr>
<td>Algebraic Curves**</td>
<td>Master in Advanced Mathematics, UB</td>
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<tr>
<td>Computational Algebra</td>
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<td>Geometrical Methods in Number Theory</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Local Algebra</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
</tbody>
</table>

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

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

(**) This course is not recommended to students who have followed the course "Geometría Algebraica" of Grau en Matemàtiques at FME.

### General information

### Study program

#### Focus Proposals

- Focus on Discrete Mathematics
- Focus on Partial Differential Equations and Analysis
- Focus on Mathematical and Computational Modelling with PDEs
- Focus on Optimization and Operation Research for Efficient Decision Making
- Focus on Modelling and Analysis in Biomedical Sciences

### Focus on Algebra, Geometry and Number Theory
Focus on Algebra, Geometry and Number Theory — Master's degree in Advanced Mathematics and Mathematical Engineering

- Focus on Dynamical Systems and Applications to Celestial Mechanics
- Focus on Geometry and its applications

Admission requirements and pre-enrolment

Double degrees

Mobility

Testimonies

Grants and student awards

Management team and location

Quality System

Master’s thesis

Current academic year information

Forthcoming defenses of master’s thesis
Focus on Dynamical Systems and Applications to Celestial Mechanics

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

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

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

<table>
<thead>
<tr>
<th>Qualitative and quantitative methods in dynamical systems</th>
<th>7.5 ECTS</th>
<th>English</th>
<th>MAMME</th>
</tr>
</thead>
</table>

Numerical methods for dynamical systems  7.5 ECTS  English  MAMME

Hamiltonian systems  7.5 ECTS  English  MAMME

Mathematical models in biology  7.5 ECTS  English  MAMME

Advanced course in partial differential equations  7.5 ECTS  English  MAMME

Dynamical systems  6 ECTS  English  Master's degree in advanced and professional mathematics (UB)

Simulation methods  6 ECTS  English  Master's degree in advanced and professional mathematics (UB)

Focus Proposals

Focus on Discrete Mathematics

Focus on Partial Differential Equations and Analysis

Focus on Mathematical and Computational Modelling with PDEs

Focus on Optimization and Operation Research for Efficient Decision Making

Focus on Modelling and Analysis in Biomedical Sciences

Focus on Algebra, Geometry and Number Theory

Focus on Dynamical Systems and Applications to Celestial Mechanics

Focus on Geometry and its applications

Admission requirements and pre-enrolment
Double degrees

Mobility

Testimonies

Grants and student awards

Management team and location

Quality System

Master’s thesis

Current academic year information

Forthcoming defenses of master’s thesis
Focus on Geometry and its applications — Master's degree in Advanced Mathematics and Mathematical Engineering — UPC.

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>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commutative Algebra (7,5 ECTS)</td>
<td>MAMME</td>
</tr>
<tr>
<td>Non-Commutative Algebra (7,5 ECTS)</td>
<td>MAMME</td>
</tr>
<tr>
<td>Differentiable Manifolds (7,5 ECTS)</td>
<td>MAMME</td>
</tr>
<tr>
<td>Algebraic Geometry (7,5 ECTS)</td>
<td>MAMME</td>
</tr>
</tbody>
</table>

https://mamme.masters.upc.edu/en/focus-proposals/focus-on-geometry
### General information

### Study program

#### Focus Proposals

- Focus on Discrete Mathematics
- Focus on Partial Differential Equations and Analysis
- Focus on Mathematical and Computational Modelling with PDEs
- Focus on Optimization and Operation Research for Efficient Decision Making
- Focus on Modelling and Analysis in Biomedical Sciences
- Focus on Algebra, Geometry and Number Theory
- Focus on Dynamical Systems and Applications to Celestial Mechanics

**Focus on Geometry and its applications**

### Admission requirements and pre-enrolment

### Double degrees

### Mobility

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Master in Advanced Mathematics, UB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry and Topology of Varieties (6 ECTS)</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Algebraic Curves (6 ECTS)</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Computational Algebra (6 ECTS)</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Local Algebra (6 ECTS)</td>
<td>6</td>
<td>Master in Advanced Mathematics, UB</td>
</tr>
<tr>
<td>Testimonies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grants and student awards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management team and location</td>
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<tr>
<td>Quality System</td>
<td></td>
<td></td>
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<tr>
<td>Master's thesis</td>
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<tr>
<td>Current academic year information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forthcoming defenses of master's thesis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**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.
Hydraulic fracture during epithelial stretching

Flow past a cilindre. Numerical solution of Navier-Stokes eq.
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>Module Name</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>Focus on Mathematical and Computational Modelling with PDEs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus on Optimization and Operation Research for Efficient Decision Making</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus on Modelling and Analysis in Biomedical Sciences</td>
<td></td>
<td></td>
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<tr>
<td>Focus on Algebra, Geometry and Number Theory</td>
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<tr>
<td>Focus on Dynamical Systems and Applications to Celestial Mechanics</td>
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<td></td>
</tr>
<tr>
<td>Focus on Geometry and its applications</td>
<td></td>
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</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.
<table>
<thead>
<tr>
<th>Testimonies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grants and student awards</td>
</tr>
<tr>
<td>Management team and location</td>
</tr>
<tr>
<td>Quality System</td>
</tr>
<tr>
<td>Master’s thesis</td>
</tr>
<tr>
<td>Current academic year information</td>
</tr>
<tr>
<td>Forthcoming defenses of master’s thesis</td>
</tr>
</tbody>
</table>
Focus on Modelling and Analysis in Biomedical Sciences

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

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

Simulation of curved cellular monolayers with computational mechanics

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Language</th>
<th>Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical models in biology</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>Mathematical Modeling with PDEs</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Numerical Methods for PDEs</td>
<td>7.5 ECTS</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Course</td>
<td>Credits</td>
<td>Language</td>
<td>Department</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------------------------</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>Numerical Modeling*</td>
<td>9</td>
<td>English</td>
<td>Màster en Enginyeria de Camins, Canals i Ports, UPC</td>
</tr>
<tr>
<td>Técnicas básicas en neurociencia**</td>
<td>5</td>
<td></td>
<td>Màster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Biología Celular y Molecular de la Neurona**</td>
<td>5</td>
<td></td>
<td>Màster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
<tr>
<td>Diseño y análisis de datos en neurociencia cognitive**</td>
<td>2.5</td>
<td></td>
<td>Màster oficial en neurociencia, UB-UPF-UDL-URV</td>
</tr>
</tbody>
</table>
We remind that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

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

(**) These courses are proposed to students willing to get a deeper focus neuroscience. Registration to these courses requires the approval of the director of the corresponding master.
<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testimonies</td>
</tr>
<tr>
<td>Grants and student awards</td>
</tr>
<tr>
<td>Management team and location</td>
</tr>
<tr>
<td>Quality System</td>
</tr>
<tr>
<td>Master's thesis</td>
</tr>
<tr>
<td>Current academic year information</td>
</tr>
<tr>
<td>Forthcoming defenses of master's thesis</td>
</tr>
</tbody>
</table>
Focus on Optimization and Operation Research for Efficient Decision Making

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

Traffic simulation system

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

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Optimization</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Optimization in Energy Systems and Markets</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Stochastic Optimization</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Large Scale Optimization</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Integer and Combinatorial Optimization*</td>
<td>5</td>
<td>Spanish</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Statistical Data Protection*</td>
<td>5</td>
<td>English</td>
<td>MESIO UPC-UB</td>
</tr>
<tr>
<td>Graph Theory*</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
</tbody>
</table>
Recall that a minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

(*) These courses are proposed to students willing to get a deeper focus on discrete and combinatorial optimization.
Mobility

Testimonies

Grants and student awards

Management team and location

Quality System

Master's thesis

Current academic year information

Forthcoming defenses of master's thesis
Focus on Partial Differential Equations and Analysis

Partial Differential Equations (PDEs) play a central role in physics, chemistry, biology, industry, mathematical finance, and image processing. Their analysis often requires deep mathematical techniques, which makes PDEs 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.
Pattern formation with reaction-diffusion systems of PDEs

Free boundaries and PDEs: the Stefan problem for melting ice

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

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

<table>
<thead>
<tr>
<th>Course</th>
<th>ECTS</th>
<th>Language</th>
<th>Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced course in PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
<tr>
<td>Mathematical Modeling with PDEs</td>
<td>7.5</td>
<td>English</td>
<td>MAMME</td>
</tr>
</tbody>
</table>
A minimum of 3 MAMME courses (22.5 ECTS) is mandatory.

Other appropriate courses (depending on the student interests) with connections to PDEs are:

Quantitative and Qualitative Methods in Dynamical Systems (Q1 MAMME), Hamiltonian Systems (Q2 MAMME), and courses within the Barcelona universities masters offer in Mathematical Finance, Mathematical Biology, Image Processing, Functional Analysis, or Differential Geometry.
<table>
<thead>
<tr>
<th>Focus on Partial Differential Equations and Analysis — Master's degree in Advanced Mathematics and Mathematical Engineerin...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double degrees</td>
</tr>
<tr>
<td>Mobility</td>
</tr>
<tr>
<td>Testimonies</td>
</tr>
<tr>
<td>Grants and student awards</td>
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</tr>
<tr>
<td>Current academic year information</td>
</tr>
<tr>
<td>Forthcoming defenses of master’s thesis</td>
</tr>
</tbody>
</table>
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**MAMME-IIT (IIT, USA)**

**MAMME-IIT master’s double degree**

MAMME students may apply to the Illinois Institute of Technology (IIT, USA) master of Science offered by the Department of Applied Mathematics of 32 credit hours (equivalent to 62 ECTS), see [https://science.iit.edu/programs/graduate/master-science-applied-mathematics](https://science.iit.edu/programs/graduate/master-science-applied-mathematics)

2 students per year are selected and nominated by FME-UPC.

Study plan:

- 1st Fall semester at FME-UPC: 30 ECTS in MAMME courses (equivalent to 9 credit hours)
- Spring semester at IIT: 9 credit hours
- Summer at IIT: 5 credit hours (thesis)
- Fall semester at IIT: 9 credit hours, including the master’s thesis defense.

Complete 2 core sequences of 4 possibilities: **Computational** (Math 577 and 578), **Discrete** (Math 553 and 554, and Math 554 prior at FME), **Stochastics** (Math 540, and 543 or 544 or 545, and Math 540 prior at FME)
Note that students are eligible for transfer credit of 9 credit hours (3 courses) in the IIT master’s degree, reducing the total cost from 32 to 23 credit hours. For transfer credit the courses Math 554 (which requires 553), Math 540 and Math 500 should be completed and successfully passed at FME during the 1st semester.

Requirements:

- 270 ECTS at FME-UPC (240 at bachelor level + 30 at MAMME)
- TOEFL ≥ 90 iBT or IELTS ≥ 6.5
- GRE general score of 304 (combined Verbal & Quantitative sections)
- 2.5 out of 6 in the Analytical section for the Department of Applied Mathematics
- 2 letters of recommendation from FME-UPC faculty

Tuition and Fees: see [http://web.iit.edu/financial-aid/tuition-fees-and-costs](http://web.iit.edu/financial-aid/tuition-fees-and-costs)

As an example, the cost for August 2015-May 2016 per credit hour is 1.313$. The final cost with the transfer credit IIT scholarship is 22.321$.

IIT application deadline: October

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**MAMME master’s thesis at IIT**

Illinois Institute of Technology (IIT, USA) agrees to consider accepting academically qualified students from FME-UPC who have completed 270 ECTS as Visiting Research Scholars, to do research in the field of Applied Mathematics up to 6 months.

Requirements:

- 270 ECTS at FME-UPC (240 at bachelor level + 30 at MAMME)
- proof of English language proficiency, intermediate level
- 2 letters of recommendation from FME-UPC faculty
- Identification of 2 professors at IIT to work with in the area of research

Tuition and fees: 2 research credits per semester, 1 research credit during summer. See costs at [http://web.iit.edu/financial-aid/tuition-fees-and-costs](http://web.iit.edu/financial-aid/tuition-fees-and-costs)

IIT application deadline: November

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**General information**
Study program

Focus Proposals

Admission requirements and pre-enrolment

Double degrees

**MAMME-IIT (IIT, USA)**

MAMME-INP Grenoble (Grenoble, France)

Mobility

Testimonies

Grants and student awards

Management team and location

Quality System

Master's thesis

Current academic year information

Forthcoming defenses of master's thesis
Master's degree in **Advanced Mathematics** and **Mathematical Engineering**

**MAMME-INP Grenoble (Grenoble, France)**

**MAMME-ENSIMAG master's double degree**

At most 4 MAMME students each academic year will be able to do a joint master double degree and obtaining

- Master Degree on Advanced Mathematics and Mathematics of Engineering (MAMME) at FME- UPC
- Master Degree the Industrial and Applied Mathematics (MSIAM) at the Grenoble INP Ensimag - UGA

Legal details can be found here ([Document 1](#), [Document 2](#), [Document 3](#)).

**Structure**

The double master's degree has a duration of three semesters, 90 ECTS, with the following general structure:

- First semester done at FME UPC (courses).
- Second semester done either at FME-UPC or Grenoble INP-UGA (master thesis)
Study plan and intensifications

We propose 4 different study plans

- Computer vision and graphics
- Mathematical Modelling
- Machine learning
- Mathematical optimization

Path 1: Computer vision and graphics

First semester (at FME-UPC)
* Graph Theory (7.5 ECTS)
* Discrete and Algorithmic Geometry (7.5 ECTS)
* Numerical Methods for PDEs (7.5 ECTS)
* Mathematical Models with PDEs or Mathematical Models in Biology (7.5 ECTS)

Second semester (at FME-UPC or Grenoble INP-UGA)
* Master Thesis (30 ECTS)

Third semester (at Grenoble INP-UGA)
* Signal and Image Processing (6 ECTS)
* Geometric Modelling (6 ECTS)
* 3D Graphics (6 ECTS)
* Advanced Imaging (3 ECTS)
* Level set methods and optimization algorithms with applications in imaging (3 ECTS)
* Model exploration for approximation of complex, high-dimensional problems (3 ECTS)
* Geophysical imaging (3 ECTS)

Path 2: Mathematical modelling

First semester (at FME-UPC)
* Mathematical Models in Biology (7.5 ECTS)
* Numerical Methods for Dynamical Systems (7.5 ECTS)
* Numerical Methods for PDEs (7.5 ECTS)
* Mathematical Models with PDEs (7.5 ECTS)

Second semester (at FME-UPC or Grenoble INP-UGA)
* Master Thesis (30 ECTS)

**Third semester (at Grenoble INP-UGA)**
* Signal and Image processing (6 ECTS)
* Computing Science for big data and HPC (6 ECTS)
* Variational methods applied to modelling (6 ECTS)
* Wavelets and applications (3 ECTS)
* Non-smooth convex optimization methods (3 ECTS)
* Numerical optimal transport and geometry (3 ECTS)
* Temporal and spatial point processes (3 ECTS)

**Path 3: Machine learning**

**First semester (at FME-UPC)**
* Graph Theory (7.5 ECTS)
* Discrete and Algorithmic Geometry (7.5 ECTS)
* Numerical Methods for PDEs (7.5 ECTS)
* Mathematical Models with PDEs or Mathematical Models in Biology (7.5 ECTS)

**Second semester (at FME-UPC or Grenoble INP-UGA)**
* Master Thesis (30 ECTS)

**Third semester (at Grenoble INP-UGA)**
* Object oriented & software design (6 ECTS)
* Applied Probability and Statistics (6 ECTS)
* Statistical Analysis and document mining (6 ECTS)
* Machine learning fundamentals (3 ECTS)
* Inverse problem and data assimilation: variational and Bayesian approaches (3 ECTS)
* Kernel methods for machine learning (3 ECTS)
* Reinforcement learning (3 ECTS)

**Path 4: Mathematical Optimization**

**First semester (at FME-UPC)**
* Graph Theory (7.5 ECTS)
* Discrete and Algorithmic Geometry (7.5 ECTS)
* Numerical Methods for PDEs (7.5 ECTS)
* Mathematical Models with PDEs or Mathematical Models in Biology (7.5 ECTS)

**Second semester (at FME-UPC or Grenoble INP-UGA)**
* Master Thesis (30 ECTS)

**Third semester (at Grenoble INP-UGA)**
* Object oriented & software design (6 ECTS)
* Applied Probability and Statistics (6 ECTS)
* Statistical Analysis and document mining (6 ECTS)
* Nonsmooth Convex Optimization Methods (3 ECTS)
* Model exploration for approximation of complex, high dimensional problems (3 ECTS)
* Efficient methods in optimization (3 ECTS)
* Numerical optimal transport and geometry (3 ECTS)
Forthcoming defenses of master's thesis
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 guide

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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: OLLI SAARI
Others:
Segon quadrimestre:
OLLI SAARI - A

PRIOR SKILLS

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

REQUIREMENTS

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.
It is helpful an undergraduate course in Functional 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 PDE and find spectral decompositions,
- learn the modern methods to solve elliptic PDE.

STUDY LOAD

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</tr>
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</table>

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

---

**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

---

**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

---

**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 guide
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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: MARIA ALBERICH CARRAMIÑANA

Others: Segon quadrimestre:
MARIA ALBERICH CARRAMIÑANA - 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.
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

Approximately 50% of class time will be dedicated to interactive master classes, in which the lecturer will discuss course topics and propose small challenges and questions to solve. The other half of the class time will be structured as a problem-solving session, in which students will solve problems from a proposed list on the blackboard, 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 students to local algebraic geometry, with a focus on plane curve singularities. It aims to provide insight into the singularity theory of plane curves and the geometric theory of valuations of the ring of convergent series of two variables over the complex numbers. The course will demonstrate that singular points of algebraic curves in the complex plane is a meeting point for various areas of mathematics.

The course will heavily rely on examples, emphasizing the geometric significance of the subject. The specific topics for the final projects will be determined based on the students' interests.

STUDY LOAD

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<td>Hours large group</td>
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</table>

Total learning time: 187.5 h

CONTENTS

**Chapter 1: Parametrizing branches of plane curves**

**Description:**

**Full-or-part-time:** 23h
Theory classes: 10h
Self study : 13h

**Chapter 2: Infinitely near points and resolutions of singularities**

**Description:**

**Full-or-part-time:** 23h
Theory classes: 10h
Self study : 13h

**Chapter 3: Topological classification of singularities**

**Description:**

**Full-or-part-time:** 23h
Theory classes: 10h
Self study : 13h
### Chapter 4: Constructions on the resolution tree

**Description:**

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

### Chapter 5: Analytic classification of plane curves

**Description:**

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

### Chapter 6: Valuations and complete ideals

**Description:**
Classification of valuations. Zariski decomposition of complete ideals.

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

### Chapter 7: Final projects

**Description:**
The final essays of the course on the topics chosen by the students will be presented by the students themselves and commented by the course lecturers.

**Full-or-part-time:** 25h  
Theory classes: 5h  
Self study : 20h

### GRADING SYSTEM

Students who solve a sufficient number of problems on the blackboard during the problem-solving class will pass the course. If they wish to improve their grade from a passing grade to a higher score, they will be assigned a final project. The final project will involve studying, writing an essay and delivering a lecture on an additional topic towards the end of the course.

Students who have not actively participated enough in the problem-solving class, or still wish to improve their grade even after completing the problem class and final project, will be required to take a final exam lasting approximately 4 hours.
EXAMINATION RULES.

The problem list for participation in the problem-solving class will be published at the beginning of each course unit. Students are expected to prepare these problems in advance at home.

The topics for optional final projects aimed at increasing grades will be proposed around Easter. Students will be responsible for preparing the lecture and the essay of the final project independently at home.

Students who choose to take the final exam will be required to do so without any notes, books, or other materials whatsoever.

BIBLIOGRAPHY

Basic:

Complementary:
Course guide
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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER
Coordinating lecturer: SIMEON MICHAEL BALL MARKS
Others: Segon quadrimestre:
SIMEON MICHAEL BALL MARKS - 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. 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 is divided in two parts: codes and cryptography. Each part consists of 26 h of ordinary classes, including theory and problem sessions.
LEARNING OBJECTIVES OF THE SUBJECT
This course aims to give a solid understanding of the uses of mathematics in Information technologies and modern communications. The course focuses on the reliable and efficient transmission and storage of the information. Both the mathematical foundations and the description of the most importants cryptographic protocols and coding systems are given in the course.

STUDY LOAD

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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 guide
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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: JUAN JOSÉ RUE PERNA
Others:
  Segon quadrimestre:
  PATRICK MORRIS - 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.
MAMME-CE2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.

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

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

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

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Total learning time: 187.5 h

**CONTENTS**

**Partially ordered sets**

**Description:**

**Full-or-part-time:** 24h 40m
- Practical classes: 4h
- Laboratory classes: 4h
- Self study: 16h 40m

**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

**Probabilistic methods in combinatorics**

**Description:**

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

**Linear algebra methods in combinatorics**

**Description:**
The polynomial method and applications. Fisher’s theorem. Applications

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

Continuous evaluation will be based on the weekly solution of exercises. There will be also a final examination. The grading will be based on the continuous evaluation during the course (60%) and the final exam (40%).

**BIBLIOGRAPHY**

**Basic:**
Course guide
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: 2023   ECTS Credits: 7.5   Languages: English

LECTURER

Coordinating lecturer: JOSEP ALVAREZ MONTANER
Others:

PRIOR SKILLS

Linear algebra, algebraic structures, topology.

REQUIREMENTS

The two first years of a degree in mathematics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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

TEACHING METHODOLOGY

Teaching Classes, resolution of problems
LEARNING OBJECTIVES OF THE SUBJECT

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

STUDY LOAD

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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:
60% Resolution of assigned exercises and/or projects
40% Final Exam

BIBLIOGRAPHY

Basic:
Course guide
34959 - CM - Computational Mechanics

Unit in charge: School of Mathematics and Statistics
Teaching unit:
749 - MAT - Department of Mathematics.
751 - DECA - Department of Civil and Environmental Engineering.
748 - FIS - Department of Physics.

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

Academic year: 2023  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: JOSE JAVIER MUÑOZ ROMERO

Others: Segon quadtrimestre:
ALVARO MESEGUER SERRANO - A
JOSE JAVIER MUÑOZ ROMERO - A
ANTONIO RODRIGUEZ FERRAN - 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.
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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.
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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

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 (tensors) and differential operators 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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<td>32.00</td>
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<tr>
<td>Self study</td>
<td>127,5</td>
<td>68.00</td>
</tr>
</tbody>
</table>

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, Fracture 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 guide
34966 - VD - Differentiable Manifolds

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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER
Coordinating lecturer: EVA MIRANDA GALCERÁN
Others: Segon quadrimestre:
EVA MIRANDA GALCERÁN - 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.
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.
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
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

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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
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 other geometries: that of contact geometry and Poisson geometry discussing the most recent progress on open conjectures in the topic.

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 40% and an essay that will contribute to the final grade in another 40%. Students would choose, together with the lecturers, a topic that complements or advances the material taught during the course, according to their mathematical interests. The remaining 20% is reserved to problem solving which can be evaluated by simply solving some assignments of the regular list of problems.

EXAMINATION RULES.

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

40% exam(s) + 40% essay + 20% problem solving

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 presential versus online teaching.
BIBLIOGRAPHY

Basic:

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-qdqYq2qhw?view_as=subscriber
Course on youtube by Professor Eva Miranda on Symplectic and Poisson Geometry
https://www.youtube.com/channel/UC8FzYf58s0EIZ-qdqYq2qhw?view_as=subscriber
Course guide
34956 - DG - Discrete and Algorithmic 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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: RODRIGO IGNACIO SILVEIRA ISOBA

Others: Primer quadrimestre:
CLEMENS HUEMER - A
JULIAN 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. 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

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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<thead>
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<tr>
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</tbody>
</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: 6h
Self study : 13h
### Decompositions and arrangements

**Description:**

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

### Proximity Structures

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

**Full-or-part-time:** 31h  
Theory classes: 10h  
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:** 37h  
Theory classes: 10h  
Laboratory classes: 2h  
Self study: 25h

### Selected theorems from Discrete Geometry

**Description:**
Helly theorem, Minkowski theorem, Erdős-Szekeres theorem, Tverberg theorem, and related theory.

**Full-or-part-time:** 57h  
Theory classes: 18h  
Self study: 39h

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**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, by presenting solutions to problems or summarizing relevant research paper, or, optionally, by an exam.
BIBLIOGRAPHY

Basic:

Complementary:

RESOURCES

Audiovisual material:
Course guide
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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: GUILLEM PERARNAU LLOBET
Others:
Primer quadrimestre:
GUILLEM PERARNAU LLOBET - A
ORIOL SERRA ALBO - A

PRIOR SKILLS

Elementary Calculus and Linear Algebra; basic notions and skills 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. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

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

TEACHING METHODOLOGY

Combination of theoretical lectures and exercise classes, with student presenting their solutions to the proposed problems. The active participation of students is a requirement for the course assessment.
LEARNING OBJECTIVES OF THE SUBJECT

Basics of Graph Theory.
Random graphs.
Applications of random graphs: the probabilistic method.
Spectral techniques to the study of graphs.
Applications of spectral techniques: expansion and random walks.
Extremal graph theory.
Applications of extremal techniques: graph limits.

STUDY LOAD

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Total learning time: 187.5 h

CONTENTS

An introduction to Graph Theory

Description:
Introduction to random graphs, main properties and classical theorems.

Specific objectives:
Basic terminology and notation
Paths and cycles
Distance and Diameter
Connectivity
Trees
Matchings
Colorings

Related competencies:
MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
MAMME-CE3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
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.

06 URI. 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.

05 TEQ. 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.

03 TLG. 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.

04 COE. 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.

07 AAT. 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.

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

Description:
Introduction to classical model of random graphs and its main combinatorial properties.

Specific objectives:
Erdos-Rényi model of random graphs.
Properties of almost all graphs.
First and second moment methods.
The probabilistic method.
Threshold functions.
Method of Moments
Chernoff’s inequality
Component phase transitions

Related competencies:
MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
MAMME-CE3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
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.

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07 AAT. 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.

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

**Description:**
Introduction to spectral graph theory, graph expanders and applications to random walks on graphs.

**Specific objectives:**
- Adjacency and Laplacian matrices.
- Courant-Fischer Theorem.
- Interlacing.
- Cospectral graphs.
- Graph invariants: independence number, chromatic number, diameter, ... Spectral gap and second largest eigenvalue.
- Isoperimetry and Cheeger's inequality.
- Matrix tree theorem.
- Shannon capacity.
- Random walks in graphs.

**Related competencies:**
- MAMME-CE4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.
- MAMME-CE3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
- 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.
- 06 URI. 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.
- 05 TEQ. 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.
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- 07 AAT. 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.

**Full-or-part-time:** 16h

Theory classes: 16h

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**Extremal Graph Theory**

**Description:**
Introduction to Extremal Graph Theory, the Szemeredi Regularity Lemma, and applications to Graph limits

**Specific objectives:**
- Mantel Theorem.
- Turán Theorem.
- Erdos-Stone-Simonovits Theorem.
- Szemeredi Regularity Lemma.
- Counting Lemma.
- Triangle Removal Lemma.
- Graph Limits

**Full-or-part-time:** 20h

Theory classes: 20h

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**GRADING SYSTEM**

The assessment of the course is as follows:
- weekly work on the proposed problems and their presentation during the lectures, 30% of the mark
- a final comprehensive exam on the course topics, 70% of the mark

**EXAMINATION RULES.**

The active participation in the course is a requirement for the final assessment.
BIBLIOGRAPHY

Basic:

Complementary:
Course guide
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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: PAU MARTIN DE LA TORRE
Others: Segon quadrimestre:
AMADEU DELSHAMS I VALDES - A
PAU MARTIN DE LA TORRE - 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:
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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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**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
Quasi-integrable Hamiltonian systems

Description:

Full-or-part-time: 26h
Theory classes: 8h
Self study: 18h

Lagrangian systems and variational methods

Description:

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

Hamiltonian Partial Differential Equations

Description:

Full-or-part-time: 4h
Theory classes: 2h
Self study: 2h

- Interactions between Dynamical Systems and Partial Differential Equations

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

Full-or-part-time: 49h 30m
Theory classes: 12h
Self study: 37h 30m

ACTIVITIES

JISD summer school

Description:
Attendance to the JISD summer school

Specific objectives:
To learn from outstanding researchers a view of the state of the art in several research topics, interacting with students of the rest of Spain and of the World.
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%). Moreover, they will attend the JISD.

BIBLIOGRAPHY

Basic:

RESOURCES

Hyperlink:
- Grup de sistemes dinàmics: https://recerca.upc.edu/sd. Pàgina web del Grup de Sistemes Dinàmics de la UPC on es descriuen diversos projectes i els investigadors que hi treballen així com diverses activitats relacionades
Course guide
200900 - ML - Machine Learning

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).
MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Optional subject).

Academic year: 2023 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 and statistical topics, such as linear algebra, calculus, probability distributions, optimization algorithms and basic multivariate 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. It is not recommended that the student acquires this knowledge from the course itself.

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; students should bring their own laptops to the classroom. Lectures will normally combine a 75% of expository classes and a 25% of guided practical work. In the expository part of the sessions, the theoretical aspects are presented, 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 RMarkdwon (or a similar tool).
LEARNING OBJECTIVES OF THE SUBJECT

Upon completion of the course, the student should have acquired advanced competences on general topics and techniques for statistical machine learning (particularly for regularization-based learning algorithms) as well as for unsupervised learning, particularly data visualization. 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

<table>
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<tr>
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<tbody>
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<td>Self study</td>
<td>127,5</td>
<td>68.00</td>
</tr>
</tbody>
</table>

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
<table>
<thead>
<tr>
<th>Course Title</th>
<th>Description</th>
<th>Full-or-part-time</th>
<th>Theory classes</th>
<th>Practical classes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gentle introduction to machine learning</strong></td>
<td>Introduction to Bayesian thinking for machine learning. Learning by solving a regularized problem. Illustrative example.</td>
<td>5h</td>
<td>2h</td>
<td>3h</td>
</tr>
<tr>
<td><strong>Learning in functional spaces</strong></td>
<td>Reproducing kernel Hilbert spaces. The representer theorem. Example 1: Kernel ridge regression. Example 2: The Perceptron and the kernel Perceptron.</td>
<td>8h</td>
<td>4h</td>
<td>4h</td>
</tr>
<tr>
<td><strong>The support vector machine for classification, regression and novelty detection</strong></td>
<td>The support vector machine (SVM) is the flagship in kernel methods. Its versions for classification, regression and novelty detection are explained and demonstrated.</td>
<td>6h</td>
<td>4h</td>
<td>2h</td>
</tr>
<tr>
<td><strong>Kernel functions in R^d</strong></td>
<td>Description and demonstration of fundamental kernel functions in R^d. Polynomial and Gaussian kernels. General properties of kernel functions.</td>
<td>4h</td>
<td>2h</td>
<td>2h</td>
</tr>
<tr>
<td><strong>Kernel functions for different data types</strong></td>
<td>Some kernel functions for different data types are presented and demonstrated, such as text, trees, graphs, categorical variables, and others.</td>
<td>6h</td>
<td>4h</td>
<td>2h</td>
</tr>
</tbody>
</table>
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. Finally, recent research on the fusion of deep neural networks and kernel functions will be presented, if time permits.

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) Practical work done throughout 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 guide
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
751 - DECA - Department of Civil and Environmental Engineering.

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

Academic year: 2023 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: MATTEO GIACOMINI

Others: Primer quadrimestre:
JEZABEL CURBELO HERNANDEZ - A
SONIA FERNANDEZ MENDEZ - A
MATTEO GIACOMINI - A
JOSE JAVIER MUÑOZ ROMERO - A

PRIOR SKILLS

Good knowledge of calculus techniques, including integral theorems. Elementary solution of ODEs and PDEs.

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 mainly consists of theoretical lectures, but it also includes problem solving and computer sessions, with numerical codes provided to illustrate the behaviour of the models.
LEARNING OBJECTIVES OF THE SUBJECT

The module provides a general overview on the use of partial differential equations (PDEs) to construct mathematical models of physical phenomena and engineering systems. By the end of the module, students are expected to be able to:
- describe basic physical phenomena using PDEs;
- provide intuitive interpretation of the operators appearing in a PDE;
- predict the physical behaviour of an engineering system in view of its mathematical description using PDEs.

STUDY LOAD

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Total learning time: 187.5 h

CONTENTS

1. Diffusion phenomena and heat transfer

Description:

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

2. Potentials in physics and technology

Description:

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

3. Modelling in continuum mechanics

Description:

Full-or-part-time: 20h
Theory classes: 20h

4. Modelling in fluid dynamics

Description:

Full-or-part-time: 20h
Theory classes: 20h
GRADING SYSTEM

50% written exam and 50% continuous assessment (assignments and exercises).

EXAMINATION RULES.

The assignments must be submitted via ATENeA by the announced deadline. Late submissions or assignments submitted using other means will not be accepted and will be graded 0. The assignments must be performed individually: students are encouraged to discuss about the assignments but the submitted work must be the result of one own efforts. Plagiarism in the assignments will be punished with a 0 in the classwork grade.

The written exam must be performed individually and will be closed-book. Plagiarism will be punished with a 0 in the module grade.

BIBLIOGRAPHY

Basic:

Complementary:
Course guide
34960 - MMB - Mathematical Models in Biology

Last modified: 01/06/2023

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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: MARTA CASANELLAS RIUS

Others:
Primer quadrimestre:
MARTA CASANELLAS RIUS - A
JESUS FERNANDEZ SANCHEZ - A
GEMMA HUGUET CASADES - A
ADRIÁN FERNANDO PONCE ÁLVAREZ - 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.
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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

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:
3. Epidemiology.

Full-or-part-time: 12h 30m
Theory classes: 2h
Laboratory classes: 2h
Self study: 8h 30m
Mathematical Models in Neuroscience

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.
6. Applications to cognitive tasks (working memory, decision making and visual perception).
7. Recurrent Neural Networks.

Full-or-part-time: 100h
Theory classes: 16h
Laboratory classes: 16h
Self study: 68h

Mathematical models in phylogenetics

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...), evolutionary distances, phylogenetic trees.

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 guide
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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: ENRIC VENTURA CAPELL

Others: Primer quadrimestre:
JOSE BURILLO PUIG - A
MALLIKA ROY - 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.

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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
Subgroups of free groups

Description:
- Nielsen-Schreier theorem
- Stallings graphs
- Main properties of the lattice of subgroups of a free group
- Finite index subgroups
- Pull-back and intersection of subgroups.

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 some exercises assigned along the development of the course. At the end of the course, there will be a written exam with two parts: (a) the development of a theoretical topic chosen by the teachers among a closed public list of topics about the contents of the course (70%); and (b) a short list of problems/exercises about the topics of the course (30%).

BIBLIOGRAPHY

Basic:

Complementary:

RESOURCES

Other resources:
Several interesting papers and notes by Chuck Miller:
Course guide
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: 2023  ECTS Credits: 7.5  Languages: English

LECTURER

Coordinating lecturer: JOAN CARLES LARIO LOYO

Others: Primer quadrimestre: JOAN CARLES LARIO LOYO - A BERNAT PLANS BERENGUER - 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.

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.
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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.

EXAMINATION RULES.

Solved exercises and works must be delivered according to schedule.

BIBLIOGRAPHY

Basic:
RESOURCES

Computer material:
- SAGE. Mathematical Software
- Matlab. Mathematical software
Course guide
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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER
Coordinating lecturer: MERCEDES OLLE TORNER
Others: Primer quadrimestre:
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.
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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
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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Total learning time: 187.5 h

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 guide
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: 2023 ECTS Credits: 7.5 Languages: English

LECTURER

Coordinating lecturer: SONIA FERNANDEZ MENDEZ
Others: Primer quadrimestre:
SONIA FERNANDEZ MENDEZ - A
ABEL GARGALLO PEIRO - A
SERGI PÉREZ ESCUDERO - A

PRIOR SKILLS
Basics on numerical methods, differential equations and calculus.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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

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

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.

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

STUDY LOAD

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

Total learning time: 187.5 h

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.
Application to the numerical modelling of flow in porous medium, and potential flow.
Introduction to a posteriori error estimation and adaptivity.
Time integration for transient problems.
Solution of the convection-diffusion equation. Stabilized formulations for convection dominated problems.
Numerical solution of linear elasticity problems.

Full-or-part-time: 32h
Theory classes: 16h
Laboratory classes: 16h

FEM for incompressible flow problems

Description:
Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition.
Introduction to the numerical solution of the incompressible Navier-Stokes equations.

Full-or-part-time: 14h
Theory classes: 7h
Practical classes: 7h
FEM for wave problems

Description:
Introduction to DG for first order conservation laws.

Full-or-part-time: 14h
Theory classes: 7h
Laboratory classes: 7h

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

BIBLIOGRAPHY

Basic:

Complementary:
Course guide
34961 - QQMDS - Quantitative and Qualitative Methods in 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: 2023 ECTS Credits: 7.5 Languages: English

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.
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

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 perturbatives techniques to study a dynamical system globally.

LEARNING OBJECTIVES OF THE SUBJECT

STUDY LOAD

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Total learning time: 187.5 h

CONTENTS

**Invariant objects in Dynamical Systems**

- **Description:**
  - Continuous and discrete Dynamical Systems.
  - Poincaré map.
  - Local behaviour of hyperbolic invariant objects. Conjugation.
  - Invariant manifolds.

  **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

Homoclinic points and chaotic Dynamics

Description:

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

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

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.

EXAMINATION RULES.

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

BIBLIOGRAPHY

Basic:
Course guide
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: 2023 ECTS Credits: 3.0 Languages: English

LECTURER

Coordinating lecturer: JUAN JOSÉ RUE PERNA
Others: Segon quadrimestre: JUAN JOSÉ RUE PERNA - A

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

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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.

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
- Analogues in Riemannian geometry

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 guide
200902 - SADEM - Seminar on Analysis, Differential Equations and Modelling

Unit in charge: School of Mathematics and Statistics
Teaching unit: 748 - FIS - Department of Physics.
749 - MAT - Department of Mathematics.
Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010).
(Optional subject).
Academic year: 2023 ECTS Credits: 3.0 Languages: English

LECTURER

Coordinating lecturer: JOSE JAVIER MUÑOZ ROMERO
Others: Segon quadrimestre:
GEMMA HUGUET CASADES - A
JOSEP JOAQUIM MASDEMONT SOLER - A
ALVARO MESEGUER SERRANO - 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/report 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 mathematical methods for the 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.

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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/report.

(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: