Guia Docent

Curs Pearson

16/17

Facultat de Matemàtiques i Estadística

1857-1936

Master in Advanced Mathematics and Mathematical Engineering

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat de Matemàtiques i Estadística

Sumari:

General information MAMME

Introduction

Admission

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General information

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

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

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

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

Duration and start date

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

Timetable and delivery

Afternoons. Face-to-face

Fees and grants

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

Language of instruction

English

Location

School of Mathematics and Statistics (FME)

Official degree

Recorded in the Ministry of Education's degree register

Double-degree agreements

Double-degree pathways with universities around the world

- Master's degree in Advanced Mathematics and Mathematical Engineering (FME) + Master of Science in Applied Mathematics (Illinois Institute of Technology). (Only FME students to Illinois, not vice versa)

FAQ (Frequently Asked Questions)

Pre-enrolment

Request information

This master General

Name

Email *

Country *

Your question *

Privacy policy

Send

General requirements

Academic requirements for admission to master's degrees

Specific requirements

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

A scientific background is required, with basic mathematical foundations. For this reason, a bachelor in mathematics, statistics, physics, engineering, economics or science is recommended. This list is non-exclusive, and all applications will be reviewed on an individual basis.

Admission criteria

The following elements will be taken into consideration during the evaluation process: academic record, CV, statement of purpose and, if deemed necessary, personal interview and recommendation letters.

Places

30

Pre-enrolment

Pre-enrolment period open.
How to pre-enrol

Enrolment

How to enrol

Legalisation of foreign documents

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

Print version

FAQ (Frequently Asked Questions)

Pre-enrolment

Request information

This master General

Name

Email *

Country *

Your question *

Privacy policy

Send

First semester

Codes and Cryptography	7.5
Differentiable Manifolds	7.5
Discrete and Algorithmic Geometry	7.5
Graph Theory	7.5
Mathematical Modelling with Partial Differential Equations	7.5
Non-Commutative Algebra	7.5
Number Theory	7.5
Numerical Methods for Dynamical Systems	7.5
Numerical Methods for Partial Differential Equations	7.5
Quantitative and Qualitative Methods in Dynamical Systems	7.5

Second semester

Advanced Course in Partial Differential Equations	7.5
Algebraic Geometry	7.5
Combinatorics	7.5
Commutative Algebra	7.5
Computational Mechanics	7.5
Hamiltonian Systems	7.5
Mathematical Models in Biology	7.5

Compulsory	ECTS
Optional	ECTS
Project	ECTS

Print version

FAQ (Frequently Asked Questions)

Professional opportunities

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

Competencies

Generic competencies

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

Specific skills

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

Print version

Organising school

School of Mathematics and Statistics (FME)

Academic coordinator

Sonia Fernández Méndez

Academic calendar

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

Academic regulations

Academic regulations for master's degree courses at the UPC

Print version

Program

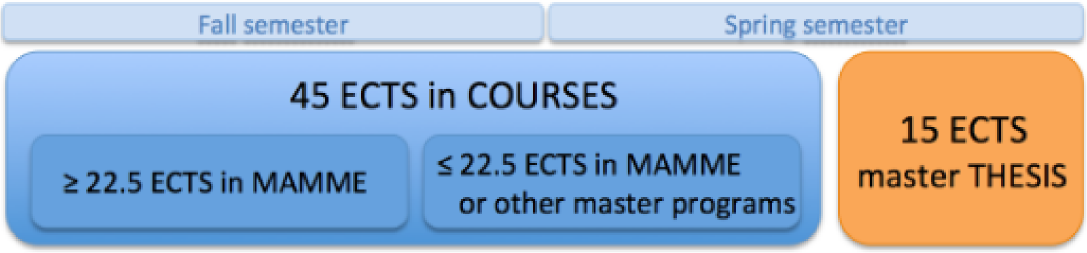
Study program

MAMME courses

Master thesis

Study program

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



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

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

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

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

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

MAMME courses

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

Field: Algebra and Geometry

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

Field: Discrete Mathematics and Algorithmics

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

Field: Modelling in Engineering and Biomedical Sciences

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

Field: Differential Equations

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

Field: Scientific Computing

Numerical Methods for Dynamical Systems (Autumn term Q1)
Numerical Methods for Partial Differential Equations (Autumn term Q1

Master's thesis

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

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

Regulations, calendar and templates

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

Templates for the document of the master thesis can be downloaded here:

- LaTeX template
- Cover page

Forthcoming defenses

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

Subjects MAMME

MAMME

Code	Subject
34950	Commutative Algebra
34952	Algebraic Geometry
34953	Number Theory
34954	Codes and Cryptography
34955	Combinatorics
34956	Discrete and Algorithmic Geometry
34957	Graph Theory
34958	Mathematical Modelling with Partial Differential Equations
34959	Computational Mechanics
34960	Mathematical Models in Biology
34961	Quantitative and Qualitative Methods in Dynamical Systems
34962	Hamiltonian Systems
34963	Advanced Course in Partial Differential Equations
34964	Numerical Methods for Dynamical Systems
34965	Numerical Methods for Partial Differential Equations
34966	Differentiable Manifolds

Last update: 12-06-2016

34950 - CALG - Commutative Algebra

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5   Teaching languages: English

Teaching staff

Coordinator: JOSEP ALVAREZ MONTANER

Others:

JOSEP ALVAREZ MONTANER - A

Prior skills

Linear algebra, algebraic structures, topology.

Requirements

The two first years of a degree in mathematics.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

Teaching methodology

Teaching Classes, resolution of problems

Learning objectives of the subject

Last update: 12-06-2016

34950 - CALG - Commutative Algebra

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

Study load

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

34950 - CALG - Commutative Algebra

Content

Rings and ideals	Learning time: 28h 20m Theory classes: 15h Self study : 13h 20m

Description:
Basics on ring theory and ideals.
Rings of fractions. Primary decomposition. Chain conditions. Noetherian and Artinian rings.

Modules	Learning time: 24h Theory classes: 12h Self study : 12h

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

Algebraic varieties	Learning time: 24h Theory classes: 12h Self study : 12h

Description:
The spectrum of a ring. Zariski topology.

Introduction to homological algebra	Learning time: 24h Theory classes: 12h Self study : 12h

Description:
Categories and functors. Complexes of modules. Derived functors.

Local algebra	Learning time: 18h 40m Theory classes: 9h Self study : 9h 40m

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

34950 - CALG - Commutative Algebra

Qualification system

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

If necessary, a final exam

Bibliography

Basic:

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

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

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

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

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

Rotman, J.J. An introduction to homological algebra. Academic Press, 1979.

Bruns, Winfried; Herzog, Jürguen. Cohen-Macaulay rings. Cambridge University Press, 1993.

Last update: 12-06-2016

34952 - AG - Algebraic Geometry

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: JAUME AMOROS TORRENT

Others: JAUME AMOROS TORRENT - A

Opening hours

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

Prior skills

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

Requirements

Basic abstract Algebra, Topology and Differential Geometry.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34952 - AG - Algebraic Geometry

Teaching methodology

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

Learning objectives of the subject

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

Study load

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

34952 - AG - Algebraic Geometry

Content

Chapter 1: Algebraic equations	Learning time: 15h Theory classes: 6h Self study : 9h

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

Chapter 2: Algebraic varieties	Learning time: 13h Theory classes: 6h Self study : 7h

Description:
Affine algebraic varieties. Nullstellensatz. Ring of regular functions. Subvarieties. Products of varieties, fibered products. Separation axiom.

Chapter 3: Projective varieties	Learning time: 9h Theory classes: 4h Self study : 5h

Chapter 4: Maps and morphisms	Learning time: 13h Theory classes: 6h Self study : 7h

Description:
Basic properties. Noether normalization theorem. Zariski's main theorem. Proper maps. Normalization. Resolution of singularities: blow-ups and Hironaka's theorem.

Chapter 5: Complex analytic varieties	Learning time: 14h Theory classes: 8h Self study : 6h

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

Chapter 6: Sheaves	Learning time: 18h Theory classes: 8h Self study : 10h
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.	

Chapter 7: Final projects	Learning time: 12h Theory classes: 4h Self study : 8h
Description: The topics of the final projects made by course students, explained by themselves and by the course lecturer.	

Qualification system

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

Regulations for carrying out activities

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

Last update: 12-06-2016

34952 - AG - Algebraic Geometry

Bibliography

Basic:

Reid, Miles. Undergraduate commutative algebra. Cambridge U.P.,

Reid, Miles. Undergraduate algebraic geometry. Cambridge U.P.,

Griffiths, Phillip ; Harris, Joseph. Principles of algebraic geometry. John Wiley and Sons,

Shafarevich, Igor. Basic algebraic geometry. 2nd. rev. and expanded ed. Berlin: Springer Verlag, 1994. ISBN 3540548122.

Complementary:

Voisin, Claire. Hodge theory and complex algebraic geometry 1. Cambridge U.P.,

Beauville, A.. Complex algebraic surfaces. Cambridge U.P.,

34953 - NT - Number Theory

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: JORDI GUARDIA RUBIES

Others:

JORDI GUARDIA RUBIES - A

Prior skills

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

Requirements

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34953 - NT - Number Theory

Teaching methodology

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

Learning objectives of the subject

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

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

Study load

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

Content

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

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

Qualification system

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

Regulations for carrying out activities

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

34953 - NT - Number Theory

Bibliography

Basic:

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

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

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

Cox, David A. Primes of the form x2 + ny2 : Fermat, class field theory, and complex multiplication. New York [etc.]: John Wiley, cop. 1989. ISBN 9780471190790.

Cohen, Henri. A Course in computational algebraic number theory. Berlin [etc.]: Springer-Verlag, cop. 1993. ISBN 3540556400.

Others resources:

Computer material

SAGE

Mathematical Software

34954 - CC - Codes and Cryptography

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

Teaching staff

Coordinator: MARIA PAZ MORILLO BOSCH

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

Prior skills

Basic probability, basic number theory and linear algebra

Requirements

Undergraduate mathematics

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34954 - CC - Codes and Cryptography

Teaching methodology

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

Learning objectives of the subject

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

Study load

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

34954 - CC - Codes and Cryptography

Content

Introduction

Learning time: 6h 15m

Theory classes: 2h
Self study : 4h 15m

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

Information and Entropy

Learning time: 18h 45m

Theory classes: 6h
Self study : 12h 45m

Description:
Uncertainty or information. Entropy. Mutual information

Source codes without memory

Learning time: 12h 30m

Theory classes: 4h
Self study : 8h 30m

Description:
Codes. Average length. Huffman codes. Extensions of a source. Theory of an noiseless communication. Notes of compression.

Channel coding

Learning time: 18h 45m

Theory classes: 6h
Self study : 12h 45m

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

Block codes

Learning time: 18h 45m

Theory classes: 6h
Self study : 12h 45m

Description:
Hamming's distance. Detection and correction of errors. Bounds. Linear codes.

Cyclic codes	Learning time: 18h 45m Theory classes: 6h Self study : 12h 45m
Description: Cyclic codes. Generator and control matrices. Factorization of x^n-1. Roots of a cyclic code. BCH codes. Primitive Reed-Solomon codes. Meggit's decoder.	

Introduction to modern cryptography	Learning time: 15h 37m Theory classes: 5h Self study : 10h 37m
Description: The setting: secure storage and symmetric key encryption. Turing machines and complexity classes. Security definitions. Adversarial models. Reductionist security proofs.	

Symmetric key cryptography	Learning time: 15h 38m Theory classes: 5h Self study : 10h 38m
Description: Symmetric key encryption. Pseudorandom generators. Block ciphers. Message authentication codes.	

Public key encryption	Learning time: 15h 37m Theory classes: 5h Self study : 10h 37m
Description: Definitions and security notions. One way functions. Probabilistic encryption. Main constructions. Homomorphic encryption. Chosen ciphertext security.	

Digital signatures	Learning time: 15h 38m Theory classes: 5h Self study : 10h 38m
Description: Security definitions. RSA and Schnorr signatures.	

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

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

Qualification system

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

Regulations for carrying out activities

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

34954 - CC - Codes and Cryptography

Bibliography

Basic:

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

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

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

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

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

Complementary:

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

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

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

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

Last update: 12-06-2016

34955 - COMB - Combinatorics

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

Teaching staff

Coordinator: MARCOS NOY SERRANO

Others:

MARCOS NOY SERRANO - A
ORIOL SERRA ALBO - A

Prior skills

Basic calculus and linear algebra. Notions of probability.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

Teaching methodology

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

Learning objectives of the subject

To use algebraic, probabilistic and analytic methods for studying combinatorial structures. The main topics of study are:

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

Study load

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

34955 - COMB - Combinatorics

Content

Partially ordered sets	Learning time: 24h 40m Practical classes: 4h Laboratory classes: 4h Self study : 16h 40m
Description: Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem	

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

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

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

Matroids	Learning time: 18h 30m Theory classes: 3h Laboratory classes: 3h Self study : 12h 30m
Description: Axioms. Transversal matroids. Greedy algorithms. The Tutte polynomial	

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

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

Enumerative combinatorics	Learning time: 32h 30m Theory classes: 5h Laboratory classes: 5h Self study : 22h 30m
Description: Symbolic and analytic methods. Symmetries and Pólya theory.	

Qualification system

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

34955 - COMB - Combinatorics

Bibliography

Basic:

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

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

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

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

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

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

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

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

Last update: 12-06-2016

34956 - DG - Discrete and Algorithmic Geometry

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

Teaching staff

Coordinator: VERA SACRISTAN ADINOLFI

Others:

JULIAN THORALF PFEIFLE - A
VERA SACRISTAN ADINOLFI - A
RODRIGO IGNACIO SILVEIRA - A

Prior skills

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

Last update: 12-06-2016

34956 - DG - Discrete and Algorithmic Geometry

Teaching methodology

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

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

Learning objectives of the subject

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

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

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

Study load

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

34956 - DG - Discrete and Algorithmic Geometry

Content

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

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

Convexity	Learning time: 19h Theory classes: 4h Laboratory classes: 2h Self study : 13h

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

Decompositions and arrangements	Learning time: 31h Theory classes: 7h Laboratory classes: 3h Self study : 21h

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

Proximity Structures	Learning time: 31h Theory classes: 7h Laboratory classes: 3h Self study : 21h

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

Polytopes and Subdivisions of Point Sets	Learning time: 38h Theory classes: 10h Laboratory classes: 3h Self study : 25h
Description: Homogeneous coordinates. Polytopes: faces and boundary structure; examples; operations on polytopes (polarity, products, etc.). Point sets: subdivisions and triangulations (including Delaunay and Voronoi).	

Lattice Geometry	Learning time: 24h Theory classes: 6h Laboratory classes: 2h Self study : 16h
Description: Examples of lattices. Ehrhart's Theorem on integer points in polytopes. Brion's Theorem.	

Symmetry	Learning time: 23h Theory classes: 6h Practical classes: 1h Self study : 16h
Description: Orbifolds and the Magic Theorem on symmetry groups in the plane. Exploitation of symmetry in linear optimization.	

Software	Learning time: 9h Laboratory classes: 2h Self study : 7h
Description: Polymake, Curved Spaces, etc.	

Qualification system

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

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

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

34956 - DG - Discrete and Algorithmic Geometry

Bibliography

Basic:

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

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

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

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

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

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

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

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

Complementary:

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

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

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

Richter-Gebert, Jürgen. Perspectives on projective geometry: a guided tour through real and complex geometry. Berlin: Springer, 2011. ISBN 9783642172854.

Others resources:

Audiovisual material

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

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

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

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

Last update: 12-06-2016

34957 - GT - Graph Theory

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

Teaching staff

Coordinator: ORIOL SERRA ALBO

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

Prior skills

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

Teaching methodology

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

Learning objectives of the subject

34957 - GT - Graph Theory

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

Study load

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

34957 - GT - Graph Theory

Content

Spectral techniques in Graph Theory

Learning time: 1h

Theory classes: 1h

Description:

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

Specific objectives:

Computation of spectra. Circulant graphs. Spectra and graph operations. Obttntion of spectral bounds for graph invariants.

Symmetries in graphs

Learning time: 1h

Theory classes: 1h

Description:

Minors and treewidth

Degree competences to which the content contributes:

Graphs on surfaces

Degree competences to which the content contributes:

Graph homomorphisms

Degree competences to which the content contributes:

Random graphs

Degree competences to which the content contributes:

Extremal Graph Theory	Learning time: 75h Theory classes: 24h 10m Practical classes: 24h 10m Assessment sessions: 3h Self study (distance learning): 23h 40m

Qualification system

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

Regulations for carrying out activities

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

Bibliography

Basic:

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

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

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

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

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

Last update: 12-06-2016

34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ

Others:

XAVIER CABRE VILAGUT - A
FERNANDO CHARRO CABALLERO - A
JUAN DE LA CRUZ DE SOLÀ-MORALES RUBIÓ - A

Prior skills

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Teaching methodology

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

Learning objectives of the subject

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

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

Study load

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

34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Content

1 Heat conduction and diffusion

Learning time: 56h 15m

Theory classes: 18h
Self study : 38h 15m

Description:
Review of Vector Calculus, Fick and Fourier laws, Random walks, self-similar solutions, Einstein calculation.
Boundart conditions, Energy Functionals, separation of variables, Thin domains, Convergence to gaussians, entropy
Steffan Problem, Black-Scholes model, Reaction-diffusion

2 Potentials in physics and technology

Learning time: 56h 15m

Theory classes: 18h
Self study : 38h 15m

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

3 Transients in continuous media

Learning time: 31h 15m

Theory classes: 10h
Self study : 21h 15m

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

4 Geometry

Learning time: 23h 26m

Theory classes: 7h 30m
Self study : 15h 56m

Description:
The Laplace-Beltrami operator.
Minimal surfaces.

5 Games and optimization	Learning time: 23h 26m Theory classes: 7h 30m Self study : 15h 56m
Description: Random games. Optimal transport.	

Qualification system

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

Bibliography

Basic:

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

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

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

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

Complementary:

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

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

Last update: 12-06-2016

34959 - CM - Computational Mechanics

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

Teaching staff

Coordinator: JOSE JAVIER MUÑOZ ROMERO

Others: JOSE JAVIER MUÑOZ ROMERO - A

Prior skills

Basic knowledge of numerical methods
Basic knowledge of partial differential equations

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34959 - CM - Computational Mechanics

Teaching methodology

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

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

Learning objectives of the subject

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

Study load

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

Content

CONTINUUM MECHANICS	Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m

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

COMPUTATIONAL ELASTICITY	Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m

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

COMPUTATIONAL DYNAMICS	Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m

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

COMPUTATIONAL PLASTICITY	Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m

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

COMPUTATIONAL FLUID DYNAMICS	Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m

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

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

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

Qualification system

Final exam, assigned problems, and course project.

34959 - CM - Computational Mechanics

Bibliography

Basic:

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

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

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

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

Complementary:

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

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

Holzapfel, Gerhard A. Nonlinear solid mechanics : a continuum approach for engineering. Chichester: John Wiley & Sons, cop. 2000. ISBN 978-0-471-82319-3.

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

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

Taber, Larry A. Nonlinear theory of elasticity. Applications in Biomechanics [on line]. 2008. Singapore: World Scientific Publishing, 2004 [Consultation: 27/05/2015]. Available on: <http://www.worldscientific.com/worldscibooks/10.1142/5452>. ISBN 9812387358.

Zienkiewicz O. C.;Taylor, R. L. The finite element method [on line]. 6th ed. Oxford: Butterworth Heinemann, 2005Available on: <http://www.sciencedirect.com/science/book/9780750664318>.

34960 - MMB - Mathematical Models in Biology

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

Teaching staff

Coordinator: JESUS FERNANDEZ SANCHEZ

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

Prior skills

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

Requirements

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
9. EFFECTIVE USE OF INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

Teaching methodology

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

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

Learning objectives of the subject

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

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

Study load

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

34960 - MMB - Mathematical Models in Biology

Content

Mathematical models in Genomics	Learning time: 75h Theory classes: 12h Laboratory classes: 12h Self study : 51h

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

Mathematical Models in Neurohysiology	Learning time: 56h 15m Theory classes: 9h Laboratory classes: 9h Self study : 38h 15m

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

Models of Population Dynamics	Learning time: 37h 30m Theory classes: 6h Laboratory classes: 6h Self study : 25h 30m

Description:
1. Modelling interactions among populations with differential equations. Stability and bifurcations.
2. One-dimensional discrete models. Chaos in biological systems.
3. Paradigms of population dynamics in current research.

Biological networks	Learning time: 18h 45m Theory classes: 3h Laboratory classes: 3h Self study : 12h 45m
Description: 1. Complex networks in biology. 2. Networks of neurons.	

Qualification system

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

34960 - MMB - Mathematical Models in Biology

Bibliography

Basic:

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

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

Murray, J.D. Mathematical biology [on line]. 3rd ed. Berlin: Springer, 2002Available on: <http://link.springer.com/book/10.1007/b98868 (v. 1) http://link.springer.com/book/10.1007/b98869 (v. 2)>. ISBN 978-0-387-95223-9.

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

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

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

Keeling, Matthew James; Rohani, Pejman. Modeling infectious diseases in humans and animals. Princeton: Princeton University Press, cop. 2008. ISBN 9780691116174.

Complementary:

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

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

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

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

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

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

Last update: 12-06-2016

34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

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

Teaching staff

Coordinator: AMADEU DELSHAMS I VALDES

Others:

AMADEU DELSHAMS I VALDES - A
PABLO MARTIN DE LA TORRE - A

Opening hours

Timetable: Make an appointment by email

Prior skills

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Teaching methodology

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

Learning objectives of the subject

Study load

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

34961 - QQMDS - Quantitative and Qualitative Methods in Dynamical Systems

Content

Invariant objects in Dynamical Systems

Learning time: 10h
Other activities: 10h

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

Perturbation theory in Dynamical Systems

Learning time: 10h
Other activities: 10h

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

Variational Aspects of Dynamics

Learning time: 10h
Other activities: 10h

Description:
Critical points of functions, Morse theory, and dynamics. The billiard problem. Twist maps. Variational description of Lagrangian systems. Local theory and the exponential map. Minimal geodesics. Minimal geodescis on compact surfaces.

Homoclinic points and chaotic Dynamics

Learning time: 10h
Other activities: 10h

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

Normal forms	Learning time: 10h Other activities: 10h

Description:
Poincaré-Dulac normal forms. Convergence: Poincaré and Siegel domains. Hamiltoniane normal forms. Bifurcations. Lie series. Construction of algebraic and analytic manipulators.

Twist maps	Learning time: 10h Other activities: 10h

Description:
The regularity Lemma. Existence of Aubry-Mather sets and homoclinic orbits. Action functionals, minimal and ordered orbits. Orbits homoclinic to Aubry-Mather sets. Nonexistence of invariant circles and localization of Aubry-Mather sets.

Qualification system

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

Regulations for carrying out activities

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

Bibliography

Basic:

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

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

Katok, Anatole; Hasselblatt, Boris. Introduction to the modern theory of dynamical systems. Cambridge [etc.]: Cambridge University Press, 1995. ISBN 0-521-34187-6.

Hasselblatt, Boris; Katok, A. B. A First course in dynamics : with a panorama of recent developments. Cambridge [etc.]: Cambridge University Press, 2003. ISBN 0-521-58304-7.

Hirsch, Morris W.; Smale, Stephen; Devaney, Robert L. Differential equations, dynamical systems, and an introduction to chaos. 3rd Edition. Amsterdam: Elsevier/Academic Press, 2013. ISBN 978-0-12-382010-5.

Last update: 12-06-2016

34962 - HS - Hamiltonian Systems

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: MARIA TERESA MARTINEZ-SEARA ALONSO

Others:

MARCEL GUARDIA MUNARRIZ - A
MARIA TERESA MARTINEZ-SEARA ALONSO - A

Prior skills

Knowledge of calculus, algebra and ordinary differential equations.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

Teaching methodology

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

34962 - HS - Hamiltonian Systems

Learning objectives of the subject

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

Study load

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

34962 - HS - Hamiltonian Systems

Content

Hamiltonian formalism

Learning time: 28h

Theory classes: 10h
Self study : 18h

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

Hamiltonian and Lagrangian systems

Learning time: 12h

Theory classes: 4h
Self study : 8h

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

Integrable and quasi-integrable Hamiltonian systems

Learning time: 12h

Theory classes: 4h
Self study : 8h

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

Invariant objects of Hamiltonian systems

Learning time: 24h

Theory classes: 8h
Self study : 16h

Description:
Continuous and discrete dynamical systems, Poincaré map. Local structure of hyperbolic invariant objects: invariant manifolds. Center manifold. Lyapunov Center Theorem.

Stability of dynamical systems and Hamiltonian systems	Learning time: 28h Theory classes: 10h Self study : 18h

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

Applications to celestial mechanics	Learning time: 34h Theory classes: 12h Self study : 22h

Description:
The two body problem, first integrals. Resolution. The three body problem, different coordinates. The restricted three body problem. Central onfigurations. Periodic orbits, invariant manifolds.

- Interactions between Dynamical Systems and Partial Differential Equations	Learning time: 49h 30m Theory classes: 12h Self study : 37h 30m

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

Planning of activities

JISD summer school

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

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

Qualification system

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

34962 - HS - Hamiltonian Systems

Bibliography

Basic:

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

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

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

Celletti, Alessandra. Stability and chaos in celestial mechanics. Springer-Praxis, 2010. ISBN 978-3-540-85145-5.

Wintner, Aurel. The analytical foundations of celestial mechanics. Dover Publications, ISBN 978-0486780603.

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

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

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

Others resources:

Hyperlink

Grup de sistemes 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

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Last update: 12-06-2016

34963 - ACPDE - Advanced Course in Partial Differential Equations

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

Teaching staff

Coordinator: XAVIER CABRE VILAGUT

Others:
XAVIER CABRE VILAGUT - A
ALBERT MAS BLESA - A

Prior skills

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

Requirements

Undergraduate courses in Partial Differential Equations and in Mathematical Analysis.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34963 - ACPDE - Advanced Course in Partial Differential Equations

Teaching methodology

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

Learning objectives of the subject

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

Study load

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

Content

Classical methods for the Poisson and heat equations	Learning time: 47h Theory classes: 15h Self study : 32h

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

Sobolev spaces and variational methods	Learning time: 47h Theory classes: 15h Self study : 32h

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

Evolution equations	Learning time: 46h 45m Theory classes: 15h Self study : 31h 45m

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

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

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

Qualification system

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

34963 - ACPDE - Advanced Course in Partial Differential Equations

Bibliography

Basic:

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

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

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

Complementary:

Struwe, Michael. Variational methods : applications to nonlinear partial differential equations and hamiltonian systems [on line]. 2nd rev. and substantially expanded ed. Berlin: Springer, 1996Available on: <http://dx.doi.org/10.1007/978-3-540-74013-1>. ISBN 3540520228.

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

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

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

Last update: 12-06-2016

34964 - NMDS - Numerical Methods for Dynamical Systems

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

Teaching unit: 749 - MAT - Department of Mathematics

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: MARIA MERCEDES OLLE TORNER

Others:

MARIA MERCEDES OLLE TORNER - A

Prior skills

Good knowledge of a programming language.

Requirements

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34964 - NMDS - Numerical Methods for Dynamical Systems

Teaching methodology

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

Learning objectives of the subject

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

Study load

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

34964 - NMDS - Numerical Methods for Dynamical Systems

Content

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

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

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

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

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

Analysis of bifurcations. Some examples.	Learning time: 15h Theory classes: 7h 30m Practical classes: 7h 30m

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Degree competences to which the content contributes:

34964 - NMDS - Numerical Methods for Dynamical Systems

Qualification system

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

Regulations for carrying out activities

No rules, in principle.

Bibliography

Basic:

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

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

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

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

Last update: 12-06-2016

34965 - NMPDE - Numerical Methods for Partial Differential Equations

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

Teaching unit: 749 - MAT - Department of Mathematics
751 - ECA - Department of Civil and Environmental Engineering

Academic year: 2016

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

ECTS credits: 7,5 Teaching languages: English

Teaching staff

Coordinator: PEDRO DIEZ MEJIA

Others:

PEDRO DIEZ MEJIA - A
SONIA FERNANDEZ MENDEZ - A
ABEL GARGALLO PEIRO - A

Prior skills

Basics on numerical methods, differential equations and calculus.

Degree competences to which the subject contributes

Specific:

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

Transversal:

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

34965 - NMPDE - Numerical Methods for Partial Differential Equations

Teaching methodology

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

Learning objectives of the subject

This course is an introduction to numerical methods for the solution of partial differential equations, with application to applied sciences, engineering and biosciences.

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

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

Study load

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

34965 - NMPDE - Numerical Methods for Partial Differential Equations

Content

Fundamentals of Finite Element Methods (FEM)

Learning time: 20h

Theory classes: 10h
Laboratory classes: 10h

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

FEM for incompressible flow problems

Learning time: 6h

Theory classes: 4h
Practical classes: 2h

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

FEM for wave problems

Learning time: 10h

Theory classes: 4h
Laboratory classes: 6h

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

Stochastic FEM	Learning time: 16h Theory classes: 8h Laboratory classes: 8h

Description:
Characterization of uncertainty in the input and output of Boundary Value Problems. Non-intrusive and intrusive approaches: Monte-Carlo and Polynomial Chaos. Reducing the stochastic dimension: Karhunen-Loeve expansion. Quick introduction to Reduced Order Models for Uncertainty Quantification.

Qualification system

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

Bibliography

Basic:

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

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

Zienkiewicz, O.C.; Taylor, R. L. The finite element method [on line]. 6th ed. Oxford: Butterworth Heinemann, 2005Available on: <http://www.sciencedirect.com/science/book/9780750664318>.

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

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

Complementary:

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

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

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

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

Last update: 12-06-2016

34966 - VD - Differentiable Manifolds

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

Teaching staff

Coordinator: MIGUEL ANDRES RODRIGUEZ OLMOS

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

Prior skills

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

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

Degree competences to which the subject contributes

Specific:

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

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
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 INFORMATI0N RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

34966 - VD - Differentiable Manifolds

Teaching methodology

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

Learning objectives of the subject

The subject focuses on some of the fundamental topics of differential geometry and its applications in different areas, as geometric mechanics, control theory, classic and quantum field theory, fluid mechanics, computer vision, geophysical dynamics, general relativity and more.

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

Study load

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

Content

Reminder of Manifold Theory and Exterior Calculus	Learning time: 12h 52m Theory classes: 4h Self study : 8h 52m

Description:
Brief survey of manifold theory and differential geometry. Manifolds, atlases, smooth maps, tangent vectors and vector fields, flows, exterior calculus.

De Rham Cohomology and Integration Theory	Learning time: 25h Theory classes: 8h Self study : 17h

Description:
We define De Rham cohomology and compare to other cohomologies. We will also introduce De Rham computation kit and Poincaré duality.

Symplectic and Poisson Geometry	Learning time: 43h 45m Theory classes: 14h Self study : 29h 45m

Description:
Introduction to symplectic and Poisson manifolds with emphasis on examples. Starting with symplectic manifolds, we will explain Moser's trick and some applications to normal form theorems such as the Darboux theorem or the Lagrangian neighbourhood theorem. Special attention will be given to examples provided by the realm of integrable systems. We end the chapter introducing the basic concepts in Poisson geometry.

Lie groups and Lie algebras. Actions on Manifolds	Learning time: 25h Theory classes: 8h Self study : 17h

Description:
Introduction to the main aspects of the theory of Lie groups and their actions on manifolds, including classic groups, subgroups, actions, orbits and quotients.

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

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

Connections and Curvature	Learning time: 18h 45m Theory classes: 6h Self study : 12h 45m

Description:
We introduce connections on principal bundles and study their existence and main constructions and properties, as curvature, holonomy, parallelism and structure equations.

Vector Bundles and Associated Bundles	Learning time: 18h 45m Theory classes: 6h Self study : 12h 45m

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

Qualification system

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

Regulations for carrying out activities

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

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

34966 - VD - Differentiable Manifolds

Bibliography

Basic:

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

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

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

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

Cannas da Silva, Anna. Lectures on symplectic geometry. Springer-Verlag, 2008.

Tu, Loring W. An Introduction to manifolds. 2nd ed. New York: Springer, cop. 2011. ISBN 9781441973993.

Kobayashi, Shoshichi; Nomizu, Katsumi. Foundations of differential geometry. New York [etc.]: John Wiley & Sons, Inc, 1996-. ISBN 978-0-471-15733-5.

Guillemin, Victor; Pollack, Alan. Differential topology. Reprint of the 1974 original. AMS Chelsea Publishing,

Warner, Frank W. Foundations of differentiable manifolds and Lie groups. New York [etc.]: Springer, cop. 1983. ISBN 9780387908946.

Complementary:

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

Audin, Michèle. Torus actions on symplectic manifolds. 2nd ed. Progress in Mathematics, 93.Birkhäuser Verlag, 2004.

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

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

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

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

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

Nakahara, Mikio. Geometry, topology, and physics. 2nd ed. New York [etc.]: Taylor & Francis, cop. 2003. ISBN 0750306068.

Holm, Darryl D; Schmah, Tanya; Stoica, Cristina; Ellis, David C. P. Geometric mechanics and symmetry : from finite to infinite dimensions. New York: Oxford University Press, cop. 2009. ISBN 9780199212910.

Gallier, Jean;Quaintance, Jocelyn. Notes on differential geometry and Lie groups. University of Pennsylvania, 2016.