UAB
Universitat Autònoma de Barcelona

Partial Differential Equations: Modelling, Analysis and Numerical Approximation

Code: 45561
Credits: 6

2026/2027

Degree programme	Type	Course
Modelling for Science and Engineering	OP	1

Contact lecturer

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Teaching staff

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Group languages

You can consult this information at the end of the document.

Prerequisites

Students should have basic knowledge of calculus, algebra and ordinary differential equations, as well as basic notions of programming.

Objectives

Many phenomena that unfold in space and/or time can be modelled by means of partial differential equations. The purpose of this course is to provide the main concepts about such models as well as numerical methods for computing their solution.

Learning outcomes

- CA18 (Computationally implement numerical analysis techniques to roughly solve partial differential equations.) Computationally implement numerical analysis techniques to roughly solve partial differential equations.
- CA19 (Integrate partial differential equations into other modelling tools in the context of multidisciplinary projects.) Integrate partial differential equations into other modelling tools in the context of multidisciplinary projects.
- CA20 (Incorporate, using partial differential equations, sustainability and/or environmental efficiency criteria in mathematical modelling projects.) Incorporate, using partial differential equations, sustainability and/or environmental efficiency criteria in mathematical modelling projects.

- KA15 (Identify the mathematical analysis methods of partial differential equations.) Identify the mathematical analysis methods of partial differential equations.
- KA16 (Recognise the role and usefulness of partial differential equations in the construction of mathematical models.) Recognise the role and usefulness of partial differential equations in the construction of mathematical models.
- SA18 (Apply models based on partial differential equations to solve specific problems.) Apply models based on partial differential equations to solve specific problems.
- SA19 (Interpret the meaning and phenomenology associated with the parameters present in partial differential equations, in order to describe specific processes.) Interpret the meaning and phenomenology associated with the parameters present in partial differential equations, in order to describe specific processes.
- SA20 (Interpret the results obtained from applying a formalised model with partial differential equations.) Interpret the results obtained from applying a formalised model with partial differential equations.

Contents

PART I: PDE MODELS AND THEIR MAIN PROPERTIES

I.0. Introduction.

I.1. The heat equation. Fourier series, orthogonal functions, inner product spaces, etc. Dirichlet, Neumann, Robin boundary conditions. Wentzell (or dynamic) boundary conditions in physics and biology.

I.2. The wave equation.

I.3. Laplace's equation in various coordinate systems (including Euclidean, polar, spherical), special functions, series solutions using special functions, etc. Harmonic functions, maximum principle. Energy functionals, etc.

I.4. Poisons's equation with various boundary conditions. Eigenvalue problems, etc.

I.5. Introduction to operator semigroups. Basic results.

I.6. PDE models of structured population dynamics

I.7. Operator semigroup methods to analyse the qualitative behaviour of structured population models. Positivity, dissipativity, irreducibility, asynchronous exponential growth. Linear stability. Various definitions of compactness. Spectral mapping theorem, etc.

PART II: NUMERICAL METHODS

II.1. Finite difference methods for scalar parabolic equations: Euler explicit, Euler implicit and Crank-Nicholson methods: Von Neumann stability test. Parabolic stability Courant-Friedrichs-Lewy condition. Examples.

II.2. Numerical methods for elliptic equations.

II.3. Numerical methods for scalar conservation laws: Finite difference methods in conservation form. Shock-capturing schemes. Monotone schemes: Lax-Friedrichs and upwind schemes. Convergence and stability conditions. Entropy-satisfying schemes. Examples.

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Studies and practical work by the student.	96	3.84	CA18, CA19, CA20, KA15, KA16, SA18, SA19, SA20
Classes of theory and exercises	30	1.2	CA18, CA19, CA20, KA15, KA16, SA18, SA19, SA20
Internship classes	8	0.32	CA18, CA19, CA20, KA15, KA16, SA18, SA19, SA20

The aim of the classes of theory, problems and practices is to give to the students the most basic knowledge about partial differential equations and their applications.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Solution of a problem with a computer	40%	8	0.32	CA18, CA19, CA20, KA15, KA16, SA18, SA19, SA20
First partial exam	30%	4	0.16	CA18, CA19, CA20, KA15, KA16, SA18, SA19,

				SA20
Second partial exam	30%	4	0.16	CA18, CA19, CA20, KA15, KA16, SA18, SA19, SA20

The assessment will consist of two partial exams and the delivery of the resolution of a problem by means of the computer.

"The commission of any irregularity in an assessment act (academic fraud, plagiarism or improper use of AI, unless such use is expressly authorized in the teaching guide), which may lead to a significant variation in the grade, means that this act will be graded with a 0. In the event that the teaching guide provides that in order to pass the subject it is an essential requirement to have obtained a minimum grade in this assessment act or that several irregularities occur in the assessment acts of the same subject, the final grade for this subject is 0. Apart from this, a disciplinary process may be initiated against the student who incurs any of these irregularities."

Bibliography

Bibliography

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P.D. Lax, Hyperbolic systems of Conservation Laws and The Mathematical Theory of Shock Waves SIAM, 1973.

R.J. LeVeque, Finite Volume Methods for Hyperbolic problems, Cambridge University Press, 2002.

Y.Pinchover, J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge 2005.

S. Salsa, Partial differential equations in action : from modelling to theory Springer, 2008.

G. Strang, Introduction to Applied Mathematics, Wellesley-Cambridge Press, (1986).

E.F. Toro, Riemann Solvers and Numerical Methods for Fluid Dynamics: A practical Introduction, Springer-Verlag, 2009.

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Software

We leave full freedom to students to use the language that suits them best to do the numerical exercises of this course.

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TEm) Theory (master)	1	English	second semester	afternoon