

Course guide

34965 - NMPDE - Numerical Methods for Partial Differential Equations

Last modified: 01/06/2023

Unit in charge:	School of Mathematics and Statistics	
Teaching unit:	751 - DECA - Department of Civil and Environmental Engineering.	
Degree:	MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).	
Academic year: 2023	ECTS Credits: 7.5	Languages: English

LECTURER

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

PRIOR SKILLS

Basics on numerical methods, differential equations and calculus.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

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

Transversal:

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

TEACHING METHODOLOGY

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

LEARNING OBJECTIVES OF THE SUBJECT

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

The course recalls the theoretical basis of the Finite Element Method (FEM) for the solution of elliptic and parabolic equations, an introduction to stabilization techniques for convection-dominated problems and the FEM for compressible flow problems, and for wave problems.

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

STUDY LOAD

Type	Hours	Percentage
Hours large group	60,0	32.00
Self study	127,5	68.00

Total learning time: 187.5 h

CONTENTS

Fundamentals of Finite Element Methods (FEM)

Description:

Basic concepts of the Finite Element Method (FEM) for elliptic and parabolic equations: strong and weak form, discretization, implementation, functional analysis tools, error bounds and convergence.

Application to the numerical modelling of flow in porous medium, and potential flow.

Introduction to a posteriori error estimation and adaptivity.

Time integration for transient problems.

Solution of the convection-diffusion equation. Stabilized formulations for convection dominated problems.

Numerical solution of linear elasticity problems.

Full-or-part-time: 32h

Theory classes: 16h

Laboratory classes: 16h

FEM for incompressible flow problems

Description:

Weak form and discretization of the Stokes equations. Stable FEM discretizations for incompressible flow problems: LBB condition.

Introduction to the numerical solution of the incompressible Navier-Stokes equations.

Full-or-part-time: 14h

Theory classes: 7h

Practical classes: 7h



FEM for wave problems

Description:

FEM solution of Helmholtz equation. Non-reflecting boundary conditions. Application to acoustics.
Introduction to DG for first order conservation laws.

Full-or-part-time: 14h

Theory classes: 7h

Laboratory classes: 7h

GRADING SYSTEM

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

BIBLIOGRAPHY

Basic:

- Wait, R.; Mitchell, A. R. Finite element 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, 2005 [Consultation: 07/07/2023]. Available on : <https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/9781856176347/the-finite-element-method-for-solid-and-structural-mechanics?via=ihub=>.
- Donea, Jean M; Huerta, A. Finite element methods for flow problems [on line]. Chichester: John Wiley & Sons, 2003 [Consultation: 19/05/2020]. Available on: <https://onlinelibrary.wiley.com/doi/book/10.1002/0470013826>. ISBN 0471496669.
- Ainsworth, M.; Oden, J. T. A posteriori error estimation in finite element analysis. New York: John Wiley & sons, 2000. ISBN 047129411X.
- Quarteroni, Alfio. Numerical models for differential problems [on line]. Springer, 2009 [Consultation: 07/07/2023]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-88-470-1071-0>. ISBN 1280384433.

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.