Course guide
250402 - MODELNUM - Numerical Modelling

Last modified: 16/06/2025

Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 9.0 **Languages:** English

LECTURER

Coordinating lecturer: Garcia Gonzalez, Alberto
Codony Gisbert, David

Others: Santos Ferreira, Denise Carina
Boerst, Andino

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
8198. The ability to address and solve advanced mathematical problems in engineering, from the scope and context of the problem to its statement and implementation in a computer program. In particular, the ability to formulate, program and apply advanced analytical and numerical calculation models to the design, planning and management of a project, as well as the ability to interpret the results obtained in the of civil engineering.

Transversal:
8562. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

8563. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

TEACHING METHODOLOGY

Taught module consists on face-to-face teaching, coursework and self-study.

For the development of the exercises and practices, work will be done in small groups or individually (work aimed at the IT classroom, exercises in the conventional classroom, etc.)

Although most of the sessions will be given in the language indicated, sessions supported by other occasional guest experts may be held in other languages.

LEARNING OBJECTIVES OF THE SUBJECT

Students will acquire an understanding of partial differential equations in mathematical physics and develop the skills to analyse and solve mathematical problems in engineering that involve these concepts. They will learn to formulate and program analytical models and numerical calculations models for design, planning and management, and to interpret the results of these models in engineering contexts.

Upon completion of the course, students will be able to:

Apply partial differential equations to engineering problems in continuous media;
Use basic software to program and obtain numerical results for complex solutions;
Analyse and solve complex boundary and initial value problems in multiple dimensions in simple geometric conditions;
Use a range of techniques including parametric analysis to evaluate the solutions found;
Use numerical analysis software to conduct sensitivity analyses of problems involving the solution of ordinary differential equations;
Use partial differential equations to solve boundary problems in a continuous medium, obtaining a numerical solution through finite difference or finite element methods;
Use numerical techniques to solve modelling problems in engineering.

Divergence theorem, Green's theorem and Stokes' theorem; Partial differential equations, existence and uniqueness of solutions, stability; Types of equations and analytical solutions in specific engineering problems; History of numerical models and their application to engineering; Numerical modelling in engineering; Number storage, algorithms and error analysis; Numerical methods for the determination of zeros of functions; Solution of systems of equations using direct numerical methods and basic interactive methods; Numerical methods for the solution of nonlinear systems of equations; Eigenvalue problems: Functional approximation; Numerical quadrature; Solution of partial different equations: Finite differences and finite elements.

Intended Learning Outcomes:
1.- To demonstrate a knowledge and understanding of: the fundamentals of the behaviour and numerical approximation of differential equations; functional approximation; truncation error and solution error; consistency, stability and convergence; direct and iterative solution of linear systems of equations and eigenvalue problems.

2.- To demonstrate an ability to (thinking skills): understand and formulate basic numerical procedures and solve illustrative problems; identify the proper methods for the corresponding problem.

3.- To demonstrate an ability to (practical skills): understand practical implications of behaviour of numerical methods and solutions; logically formulate numerical methods for solution by computer with a programming language (Matlab or Octave).

4.- To demonstrate an ability to (key skills): study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

STUDY LOAD

Type	Hours	Percentage
Hours small group	19,5	8.67
Hours large group	41,9	18.63
Self study	144,0	64.03
Hours medium group	19,5	8.67

Total learning time: 224.9 h

CONTENTS

1.- Basics on modeling and programming

Description:
Introduction to programming in MATLAB.
Introduction to the concept of mathematical modelling

Full-or-part-time: 34h
Theory classes: 8h
Practical classes: 4h
Self study : 22h

2.- Modeling with ODEs

Description:
General approach: reduction to first order, initial value problems.
Methods based on approximation of the derivative: explicit and implicit Euler. Stability analysis.
Boundary value problems.

Full-or-part-time: 44h
Theory classes: 8h
Practical classes: 4h
Laboratory classes: 4h
Self study : 28h

3.- Modeling with PDEs

Description:
Mathematical notations for algebraic and differential operations involved in mathematical modeling.
Gradient, divergence, curl, matrix and vector calculus.
Introduction to modelling physical phenomena using partial differential equations. Application examples and types of PDEs.

Full-or-part-time: 44h
Theory classes: 8h
Practical classes: 4h
Laboratory classes: 4h
Self study : 28h

4.- Finite Differences

Description:
Numerical differentiation. Resolution of PDEs by the finite difference method using explicit and implicit time integration.

Full-or-part-time: 44h
Theory classes: 8h
Practical classes: 4h
Laboratory classes: 4h
Self study : 28h

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5.- Introduction to FEM

Description:
Introduction to the finite element method for modeling physical processes: 1D FEM, 2D FEM (weak shapes, boundary conditions, discretization, assembly...), programming, pre and post processing of problems solved by finite elements.

Full-or-part-time: 44h
Theory classes: 8h
Practical classes: 4h
Laboratory classes: 4h
Self study : 28h

Tests

Description:
Midterm test, final test

Full-or-part-time: 14h
Theory classes: 4h
Self study : 10h

GRADING SYSTEM

1. The subject is assessed based on the following elements:
* Class work (CW), to be done individually or in teams.
* Two tests (T1 and T2) that are strictly individual.

2. Class work (CW) refers, among others, to:
* Exercises in the classroom.
* Practices with computer.

3. The contents of the T1 and T2 tests will be in accordance with all the material taught since the beginning of the course.

4. Academic dishonesty (including, but not limited to, communication during tests, plagiarism and falsification of results) will be severely punished, in accordance with current academic regulations: any act of this nature implies a final grade of 0 in the subject.

5. The final grade of the subject is obtained according to

Note = Max(0.3*T1 + 0.7*T2, T2)*0.8 + CW*0.2

EXAMINATION RULES.

Will be discussed in class.

BIBLIOGRAPHY

Basic:
- Zienkiewicz, O.C.; Morgan. K. Finite elements and approximation. Mineola, NY: Dover, 1983. ISBN 9780486453019.
- Quarteroni A.; Saleri, F.; Gervasio, P. Scientific computing with MATLAB and Octave. 3rd ed. Heidelberg: Springer-Verlag, 2010. ISBN 9783642124297.

Complementary:
- Huerta, A.; Sarrate, J.; Rodríguez-Ferran, A. Métodos numéricos: introducción, aplicaciones y programación [on line]. Barcelona: Edicions UPC, 2001 (Errores, Sistemas de ecuaciones) [Consultation: 15/01/2021]. Available on: http://hdl.handle.net/2099.3/36258.

ISBN 8483015226.
- Hoffman, J.D. Numerical methods for engineers and scientists. 2nd ed. rev. and exp. New York: Marcel Dekker, 1992. ISBN 0824704436.
- Trefethen, L.N.; Bau III, D. Numerical linear algebra. SIAM, 1997. ISBN 9780898713619.
- Shampine L.F. Numerical solution of ordinary differential equations. CRC Press, 1994. ISBN 0412051516.
- Stoer, J.; Bulirsch, R. Introduction to numerical analysis. Springer-Verlag, 2002. ISBN 9781441930064.
- Recktenwald, G.W. Numerical methods with MATLAB: implementations and applications. Upper Saddle River: Prentice Hall, 2000. ISBN 0201308606.