Course guide
250224 - METNUMINF - Numerical Methods and Informatics

Last modified: 21/11/2022

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

Degree: **Academic year:** 2022 **ECTS Credits:** 7.5
Languages: English

LECTURER

Coordinating lecturer: JOSE SARRATE RAMOS

Others: PEDRO DIEZ MEJIA, ABEL GARGALLO PEIRO, DAVID MODESTO GALENDE, ESTHER SALA LARDIES, JOSE SARRATE RAMOS

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
3088. Knowledge and understanding of the functioning of ecosystems and environmental factors
3098. Basic knowledge of computer use and programming, operating systems, databases and software as applied to engineering

Transversal:
592. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
596. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
599. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 3. Planning and using the information necessary for an academic assignment (a final thesis, for example) based on a critical appraisal of the information resources used.
602. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
584. 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.

TEACHING METHODOLOGY

The teaching activity that takes place throughout the course consists of: fifteen weeks of face-to-face teaching, directed personal work and self-learning. In addition to the 4 hours per week in theclassroom, 6 hours per week should be devoted, on average, to directed personal work and self-learning.

At least half of the class hours are dedicated to working in small groups (work aimed at thecomputer room, 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

Computers and software for mathematical numerical analysis; Numbers, algorithms and error analysis; Determining the root of a function; Solving systems of equations by means of direct numerical methods and basic iterative methods; Solving nonlinear systems of equations; Estimation and interpolation; Numerical quadrature; Solving ordinary differential equations.

Upon completion of the course, students will have acquired the ability to: 1. Use standard computer tools to solve basic problems (e.g. measurements). 2. Use numerical analysis software to carry out a sensitivity analysis of a problem in which an ordinary differential equation is solved. 3. Solve engineering problems using numerical techniques.

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The desired learning objectives are:

1 .- To demonstrate knowledge and understanding of the properties and characteristics of basicnumerical methods for: solving nonlinear scalar equations; solving linear systems of equations,functional approximation; numerical integration and solving ordinary differential equations.

2 .- To demonstrate the ability to (thinking skills): understand and formulate numerical proceduresin order to solve basic engineering problems and identify appropriate methods for that problem.

3 .- Demonstrate the ability to (practical skills): understand the practical consequences of thebehavior of numerical methods and solutions; logically formulate numerical methods for thecomputer solution in a programming language (Matlab).

4 .- Demonstrate the ability to (key skills): study independently, use the resources of the library,use a personal computer for basic programming, take notes efficiently and manage working time.

STUDY LOAD

Type	Hours	Percentage
Guided activities	7,5	4.00
Hours large group	18,8	10.02
Hours small group	37,5	19.99
Hours medium group	18,8	10.02
Self study	105,0	55.97

Total learning time: 187.6 h

CONTENTS

Introduction to numerical modeling and programming

Description:
Introduction to modeling
Introduction to programming in MATLAB.
Concept and definitions of error (absolute, relative, rounding, truncation, significant digits) and their propagation.

Specific objectives:
Be able to develop simple programs in MATLAB.
To know the representation of integers and real numbers in a computer.
To know the concept and definitions of error and understand how they affect the numerical calculation.

Full-or-part-time: 33h 36m
Theory classes: 2h
Laboratory classes: 12h
Self study : 19h 36m

Root finding

Description:
Basic concepts of iterative methods: consistency, linear, superlinear or p-order convergence, asymptotic factor.
Methods: Newton, secant, Whittaker.
Solving engineering problems that deal with nonlinear scalar equations.

Specific objectives:
Understand the operation of iterative methods, differentiating them from methods with a finite number of operations.
To know the properties, advantages and disadvantages of the usual iterative schemes.
To know how to choose the most appropriate method in each case.
To know how to analyze, implement and interpret the results of iterative methods.

Full-or-part-time: 21h 36m
Theory classes: 4h
Laboratory classes: 5h
Self study : 12h 36m

Systems of linear equations

Description:
Classification and definitions.
Elimination methods: Gauss
Factorization methods: Crout and Cholesky
Solving engineering problems that involve solving systems of linear equations

Specific objectives:
To know the classification of methods for solving systems of linear equations.
To know the range of applicability of each method and its computational advantages and disadvantages.
To know how to implement the resolution methods presented.
To know how to identify the practical influence of the number of condition, preconditioners ...

Full-or-part-time: 31h 12m
Theory classes: 5h
Laboratory classes: 8h
Self study : 18h 12m

Functional Approximation

Description:
General approach: types and criteria of approximation
Polynomial interpolation
Least squares
Sectional approximation
Solving engineering problems involving the approximation of functions and data

Specific objectives:
To demonstrate knowledge and understanding of:
- the criteria and types of functional approximation and their advantages and disadvantages,
- Lagrange interpolation and its error and an ability to use it,
- the least squares problem, namely to deduce the normal equations and understand the approximation orthogonality,
- splines.

To demonstrate an ability to use and code some intrinsic functions to approximate a data set.
Be able to solve functional approximation problems

Full-or-part-time: 24h
Theory classes: 4h
Laboratory classes: 6h
Self study : 14h

Test #1

Description:
Resolution of assessment #2

Full-or-part-time: 12h
Practical classes: 2h
Laboratory classes: 3h
Self study : 7h

Numerical Integration

Description:
General approach, eg with trapezoidal rule
Definition of order of a quadrature
Quadrature classification
Newton-Cotes formulas
Gauss quadrature
Composite formulae
Analyze and discuss convergence of the following quadratures:
- Newton-Cotes and Gauss-Legendre as the number of integration points increases,
- composite formulae as the number of intervals increases.

Solving engineering problems involving the evaluation of integrals numerically

Specific objectives:
To demonstrate knowledge and understanding of:
- The basis of numerical integration,
- The classification of quadratures,
- The basis of the Newton-Cotes and Gaussian quadratures,
- The composite quadratures and their advantages and disadvantages.

To demonstrate an ability to:
- Define a quadrature if the integration points are given,
- Use Newton-Cotes and Gaussian quadratures, choosing the correct one in terms of accuracy and computational cost,
- Use composite quadratures.

To demonstrate an ability to apply all the concepts of numerical integration to the FEM.
To demonstrate an ability to implement an algorithm for numerical integration.
To demonstrate an ability to implement an algorithm for composite formulae.
Be able to solve problems involving numerical integration methods

Full-or-part-time: 24h
Theory classes: 4h
Laboratory classes: 6h
Self study : 14h

Modeling with Ordinary Differential Equations (ODEs)

Description:
General approach: reduction to first order, initial value (IVP.
Methods based on the approximation of the derivative: Euler,
backward Euler.
Truncation error, consistency, local and global error, order.
Single step methods (Runge-Kutta) methods: second and fourth order.
Solving engineering problems described using EDOs

Specific objectives:
Understand the concept of well-posed initial value problems (IVP).
Ability to identify and classify a problem of ODEs (in any order and dimension).
Ability to rewrite high-order ODEs as a system of first order ODEs.
Ability to identify Initial Value Problems (IVP) and Boundary Problem (BP).
Understand the concepts of convergence and order of convergence.
Knowledge of the basic properties of Runge- Kutta methods.
To demonstrate an ability to model an engineering problem as a system of ODEs.
To demonstrate an ability to use a library for the numerical solution of ODEs.
Modelling and numerical resolution of engineering problems governed by ODEs.

Full-or-part-time: 28h 47m
Theory classes: 5h
Laboratory classes: 7h
Self study : 16h 47m

Test #2

Full-or-part-time: 4h 48m
Laboratory classes: 2h
Self study : 2h 48m

GRADING SYSTEM

1. The module is graded with the following elements:
* Class work (CW), to be carried out either individually or in teams.
* Two tests (T1and T2), which are strictly individual.

2. Class work (CW) refers, among others, to:
* Exercises or quiz in the classroom.
* Assignments in the computer room.
* Participation in class.

3. Tests T1and T2 will cover all the topics presented from the beginning of the module.

4. The final mark for the module is obtained as

Mark = (0.5*T1 + 0.5*T2)^0.75 * CW^0.25

5. Academic dishonesty (including, among others, communication during tests, plagiarism and falsification of results) will be severely punished, in accordance with current academic regulations: any such act will imply a final mark of 0 in the module.

EXAMINATION RULES.

Will be discussed in class.

BIBLIOGRAPHY

Basic:

- Chapra, S.C.; Canale, R.P. Numerical methods for engineers [on line]. 8th ed. New York: McGraw-Hill, 2021 [Consultation: 20/01/2021]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=8100. ISBN 9781260571387.
- Recktenwald, G.W. Numerical methods with MATLAB: implementations and applications. Upper Saddle River: Prentice Hall, 2000. ISBN 0201308606.
- Burden, R.L.; Faires, J.D.; Burden, A.M. Numerical analysis. 10th ed. Boston, MA: Cengage Learning, 2016. ISBN 9781305253667.

Complementary:

- Hoffman, J.D.. Numerical methods for engineers and scientifists. 2nd ed. New York: Marcel Dekker, 2001. ISBN 0824704436.
- Huerta, A.; Sarrate, J.; Rodríguez-Ferran, A. Métodos numéricos: introducción, aplicaciones y programación [on line]. Barcelona: Edicions UPC, Universitat Politècnica de Catalunya, 2001 [Consultation: 15/01/2021]. Available on: http://hdl.handle.net/2099.3/36258. ISBN 8483015226.