Course guide
2500017 - MGECNUMENG - Numerical Methods in Engineering

Last modified: 01/10/2023

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

Degree: BACHELOR'S DEGREE IN CIVIL ENGINEERING (Syllabus 2020). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: JOSE SARRATE RAMOS

Others: MIQUEL AGUIRRE FONT, DAVID CODONY GISBERT, ESTHER SALA LARDIES, JOSE SARRATE RAMOS

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
14394. Basic knowledge about the use and programming of computers, operating systems, databases and computer programs with engineering application. (Basic training module)

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 the classroom, 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 the computer 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

Knowledge of a high-level programming language. Roots of functions. Solving systems of equations by means of direct numerical methods and basic iterative methods. Functional approach. Numerical quadrature. Solving Ordinary differential equations

1 Ability to use standard computer tools to solve basic problems (eg, measurements).
2 Ability to use a numerical analysis program to perform a sensitivity analysis of a problem in which an ordinary differential equation is solved.
3 Ability to solve an engineering problem using numerical techniques.

Basic concepts on the use and programming of computers and knowledge to program numerical models in engineering problems. Knowledge of computers and programs for mathematical numerical analysis. Knowledge of numbers, algorithms and error analysis. Knowledge for determining roots of functions. Knowledge for the solution of systems of equations by numerical direct methods and by basic iterative methods. Knowledge of the solution of nonlinear systems of equations. Approach and interpolation. Knowledge for numerical integration by means of quadratures. Knowledge for solving ordinary differential equations.

The desired learning objectives are:

1 .- To demonstrate knowledge and understanding of the properties and characteristics of basic numerical 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 procedures in 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 the behavior of numerical methods and solutions; logically formulate numerical methods for the computer 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
Self study	84,0	56.00
Hours medium group	24,0	16.00
Hours large group	30,0	20.00
Guided activities	6,0	4.00
Hours small group	6,0	4.00

Total learning time: 150 h

CONTENTS

Basics on 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: 28h 47m
Theory classes: 2h
Laboratory classes: 10h
Self study : 16h 47m

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: 14h 23m
Theory classes: 3h
Laboratory classes: 3h
Self study : 8h 23m

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: 24h
Theory classes: 4h
Laboratory classes: 6h
Self study : 14h

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: 19h 12m
Theory classes: 4h
Laboratory classes: 4h
Self study : 11h 12m

Test #1

Description:
Resolution of assessment #1

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:
o 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.

Full-or-part-time: 19h 12m
Theory classes: 4h
Laboratory classes: 4h
Self study : 11h 12m

Modelling 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 ODEs

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: 21h 36m
Theory classes: 4h
Laboratory classes: 5h
Self study : 12h 36m

Test #2

Description:
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.
* Three tests (T1, T2 and T3), 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. The T1 test corresponds to a programming validation test. Tests T2 and T3 will cover all the topics presented from the beginning of the module.

4. The final mark for the module is obtained as

Mark = (0.1*T1 + 0.45*T2 + 0.45*T2)*0.85 + CW* 0.15

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.

Criteria for re-evaluation qualification and eligibility: students that failed the ordinary evaluation and have regularly attended all evaluation tests will have the opportunity of carrying out a re-evaluation test during the period specified in the academic calendar. Students who have already passed the test or were qualified as non-attending will not be admitted to the re-evaluation test. The maximum mark for the re-evaluation exam will be five over ten (5.0). The non-attendance of a student to the re-evaluation test, in the date specified will not grant access to further re-evaluation tests. Students unable to attend any of the continuous assessment tests due to certifiable force majeure will be ensured extraordinary evaluation periods.

These tests must be authorized by the corresponding Head of Studies, at the request of the professor responsible for the course, and will be carried out within the corresponding academic period.

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:

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