Course guide
250325 - METNUMER - Numerical Methods

Last modified: 06/10/2020

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

Degree: BACHELOR'S DEGREE IN GEOLOGICAL ENGINEERING (Syllabus 2010). (Compulsory subject).

Academic year: 2020 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: ALBERTO GARCIA GONZALEZ

Others: ALBERTO GARCIA GONZALEZ

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
4050. 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.
595. TEAMWORK - Level 2. Contributing to the consolidation of a team by planning targets and working efficiently to favor communication, task assignment and cohesion.
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 course consists of 3.6 hours per week of classroom activity (large size group).

The 1.8 hours in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

The rest of weekly hours devoted to laboratory practice.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, program of learning and assessment activities conducted and literature.

LEARNING OBJECTIVES OF THE SUBJECT

Students will acquire an understanding of the basic concepts of numerical methods, such as interpolation, integration and the solution of systems of equations. They will also learn how these concepts apply to basic and applied technological problems.

Upon completion of the course, students will be able to: 1. Use standard software to solve basic problems;
2. Use numerical analysis software to conduct sensitivity analyses of problems involving the solution of ordinary differential equations;
3. Use numerical techniques to solve engineering problems.

Numbers, algorithms and error analysis; Determination of zeros of functions; Solution of systems of equations using direct methods and basic iterative methods; Solution of nonlinear systems of equations; Eigenvalue problems: Approximation and interpolation; Numerical quadrature; Computers and programming, operating systems, databases and engineering software

STUDY LOAD

Type	Hours	Percentage
Hours small group	26,0	17.33
Hours large group	26,0	17.33
Guided activities	6,0	4.00
Hours medium group	8,0	5.33
Self study	84,0	56.00

Total learning time: 150 h

CONTENTS

Introduction to Programming in Matlab

Description:
Description of the Matlab programming environment. Constants and variables. Arithmetic Operators. Intrinsic functions of Matlab. Basic I/O functionst. Matlab files.
Definition of vectors. Arithmetic Operators and functions with vectors. Curve plotting. Definition of arrays. Arithmetic Operators and functions with arrays. Surface plotting.
Defining functions in a file of Matlab. Using functions.
Conditional Structures: If block. Relational operators. Structures of repetition: while and do blocks. Statements break and return.
Solving engineering problems with the computer

Specific objectives:
To know the Matlab environment.
Being able to draw curves and surfaces using Matlab
To know the basics of structured programming
To know the flow control statements
Being able to develop applications in Matlab

Full-or-part-time: 28h 47m
Laboratory classes: 12h
Self study : 16h 47m

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Error propagation

Description:
Introduction. Computer representation of integers and real numbers. Rounding error and truncation error. Number of significant digits. Error propagation.
Case studies that show the problems generated by the propagation of rounding error.

Specific objectives:
To know the representation of integers and real numbers in the computer.
Understand the concept and definitions of the error. To know that it can increase with the arithmetic operations

Full-or-part-time: 9h 36m
Theory classes: 2h
Laboratory classes: 2h
Self study : 5h 36m

Roots of nonlinear functions

Description:
Motivation. General approach. Bisection method. Practical convergence criteria. Order of convergence.
Newton's method. Analysis of the order of convergence. Modified methods: the secant method and the Whittaker method.
Root finding techniques for solving problems in engineering
Solving root finding problems

Specific objectives:
Understand how iterative methods work and their requirements
To know the basic properties of Newton methods
Be able to choose the most appropriate method to solve an engineering problems. To analyze and interpret the numerical results.
Applying the knowledge acquired on iterative methods for zeros of functions to solve problems.

Full-or-part-time: 19h 12m
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 2h
Self study : 11h 12m

Solving systems of linear equations

Description:
Motivation. Classification of the methods. Solving trivial systems.
Introduction to elimination methods. Properties and algorithm of the Gauss method. Other methods.
Introduction to decomposition methods. Classification. Properties and algorithm of the Crout method. Properties ans algorithm of the Cholesky method
Applying linear system methods to solve engineering problems
Introduction to iterative methods. Condition number. Algorithms and properties of stationary methods. Practical convergence criteria.
Introduction. Equivalence with the minimization problem. Steepest descent method. Algorithm and properties of the conjugate gradient method.
Solving problems on methods for systems of linear equations.

Specific objectives:
Know the classification of methods for solving systems of linear equations.
To know the properties of the elimination methods.
To know the properties of the decomposition methods.
Be able to choose the most appropriate method to solve an engineering problems. To analyze and interpret the numerical results.
Understand how iterative methods can be used to solve a linear system and their requirements
To demonstrate knowledge and understanding of the conjugate gradient method and how to implement it.
Applying the knowledge about methods for systems of linear equations to solve problems.

Full-or-part-time: 38h 24m
Theory classes: 10h
Practical classes: 2h
Laboratory classes: 4h
Self study : 22h 24m

Approximation and interpolation

Description:
Introduction to interpolation. General approach. Fundamental theorem of interpolation. Lagrange interpolation.
Introduction to sectional interpolation. General approach. Spline C0. Splines C1. Limitations of the interpolation with splines.
Motivation. General approach. Normal equations. Linear regression. Using orthogonal polynomials.
Application of interpolation and approximation techniques to solve engineering problems
Solving problems on approximation and interpolation.

Specific objectives:
Learn the criteria and the types of functional approximation and learn the properties and how to use the Lagrange interpolation.
To know and use the polynomial sectional interpolation .
Understand and know the basic properties of least squares problem.
Be able to choose the most appropriate method to solve an engineering problems. To analyze and interpret the numerical results.

Applying the knowledge acquired on interpolation and approximation methods to solve problems.

Full-or-part-time: 24h
Theory classes: 6h
Practical classes: 2h
Laboratory classes: 2h
Self study : 14h

Numerical integration

Description:
Introduction to numerical integration. General approach. Classification. Newton-Cotes rule. Composite rules.
Introduction to Gaussian integration. Problem statement. Orthogonal polynomials. Gaussian quadratures.
Applying numerical integration techniques to solve engineering problems.
Solving problems on numerical integration.

Specific objectives:
To know the classification of numerical integration methods. To understand the basics of Newton-Cotes quadratures. To know the advantages and disadvantages of composite quadratures.
To understand the basics of Gauss quadratures. To know the convergence of studied quadratures
Be able to choose the most appropriate method to solve an engineering problems. To analyze and interpret the numerical results.

Applying the knowledge acquired on integration methods to solve problems.

Full-or-part-time: 24h
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 4h
Self study : 14h

GRADING SYSTEM

The subject will be evaluated through two theoretical-practical exams (T1 and T2). All are strictly individual and not eliminatory. The exams will be held in computer rooms, consist of theory exercises, exercises to be solved and programming exercises, whose codes will have to be delivered through the Virtual Campus ATENEA at the end of the exam. - The T1 exam will be a partial exam and will take place approximately halfway through the second semester. The date and the exact contents that enter for the T1 exam will be published on the website of the Virtual Campus ATENEA at the beginning of the second semester. - The T2 exam will be a final exam, where it will enter the complete topics of the subject. The date of T2 exam will be published on the website of the Virtual Campus ATENEA at the beginning of the second semester. The final grade of the subject will be obtained following the following formula: Final Note = max (0.3 * T1 + 0.7 * T2, T2) if T1 greater than or equal to 2 over 10 Final Note = 0.3 * T1 + 0.7 * T2 if T1 < 2 out of 10 That is, it will be the maximum between the grade obtained by the calculation (0.3 * T1 + 0.7 * T2) or the grade of the final exam T2. To be eligible for this scoring criterion, the student must have obtained a minimum score of 2 out of 10 in T1, otherwise the final grade will necessarily be obtained by calculating NotaFinal = 0.3 * T1 + 0.7 * T2.

EXAMINATION RULES.

Good Practices and Behavior Academic dishonesty (including, among others, 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. Criteria admission to reevaluation Students suspended in the regular evaluation will have the option to perform a re-evaluation test. Students who have already passed it will not be able to take the re-evaluation test of the subject. In the same way, students who have not presented the exams of the ordinary evaluation will not be able to take the re-evaluation test of the subject. The maximum score in the case of taking the re-evaluation test will be five (5.0). The non-attendance of a student summoned to the re-evaluation test, held during the period established, may not lead to the performance of another test with a later date.

BIBLIOGRAPHY

Basic:

- Recktenwald, G.W. Numerical methods with MATLAB: implementations and applications. Upper Saddle River: Prentice Hall, 2000. ISBN 0201308606.
- Mathews, J.H.; Fink, K.D. Métodos numéricos con MATLAB. 3a ed. Madrid: Prentice Hall, 2000. ISBN 8483221810.
- Kincaid, D.; Cheney, W. Análisis numérico: las matemáticas del cálculo científico. Argentina: Addison-Wesley Iberoamericana, 1994. ISBN 0201601303.
- Huerta, A.; Sarrate, J.; Rodríguez-Ferran, A. Métodos numéricos : introducción, aplicaciones y programación [on line]. Reimpressió. Barcelona: Edicions UPC, Universitat Politècnica de Catalunya, 2009 [Consultation: 15/01/2021]. Available on: http://hdl.handle.net/2099.3/36258. ISBN 8483015226.
- Isaacson, E.; Keller, H.B. Analysis of numerical methods. New York: Dover, 1994. ISBN 0486680290.

Complementary:

- Nakamura S.. Análisis numérico y visualización gráfica con Matlab. México: Prentice-Hall Hispanoamericana, 1997. ISBN 9688808601.
- Burden, R.L.; Faires, J.D.; Annette, M. Análisis numérico. 10a ed. Mexico DF: Cengage Learning, 2017. ISBN 9786075264042.
- Ralston, A.; Rabinovitz, P. A first course in numerical analysis. 2a ed. rev. Mineola (N.Y.): Dover, 2001. ISBN 048641454X.
- Hoffman, J.D. Numerical methods for engineers and scientists. 2nd ed. rev. and exp. New York: Marcel Dekker, 2001. ISBN 0824704436.
- Hildebrand, F.B.. Introduction to numerical analysis. 2nd ed. New York: Dover Publications, 1987. ISBN 0486653633.