# Numerical methods in biomedicine

**Academic Year: ( 2023 / 2024 )** **Review date: 19/12/2023 14:01:06**

**Department assigned to the subject: Mathematics Department**

**Coordinating teacher: BAYONA REVILLA, VICTOR**

**Type: Basic Core ECTS Credits : 6.0**

**Year : 2 Semester : 2**

**Branch of knowledge: Engineering and Architecture**

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Calculus I, Calculus II, Linear Algebra, Differential Equations, Computer Programming, Systems and Signals.

## LEARNING OUTCOMES

RA1: Acquire knowledge and understanding of the basic general fundamentals of engineering and biomedical sciences.
RA2: Be able to solve basic engineering and biomedical science problems through a process of analysis, identifying the problem, establishing different methods of resolution, selecting the most appropriate one and its correct implementation.
CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CG1: Adequate knowledge and skills to analyse and synthesise basic problems related to engineering and biomedical sciences, solve them and communicate them efficiently.
CG3: Knowledge of basic scientific and technical subjects that enables them to learn new methods and technologies, as well as providing them with great versatility to adapt to new situations.
CG4: Ability to solve problems with initiative, decision-making, creativity, and to communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the biomedical engineer's activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG8: Ability to solve mathematical, physical, chemical and biochemical problems that may arise in biomedical engineering.
CG12: Ability to solve mathematically formulated problems applied to biology, physics and chemistry, using numerical algorithms and computational techniques.
ECRT17: Ability to solve mathematically formulated problems, whether in physics, chemistry, biology, etc., using numerical algorithms and computational techniques.
CT1: Ability to communicate knowledge orally and in writing to both specialised and non-specialised audiences.

## OBJECTIVES

Using NUMERICAL METHODS (NM) to calculate approximate solutions of models of physiological, cellular, and molecular systems.

Studying the stability and accuracy of NM.

Calculating numerical solutions of systems of nonlinear equations.

Approximating the minimum of a function of several variables.

Developing, analyzing, and implementing finite difference methods.

Solving ordinary differential equations and systems by means of numerical integration methods.

Using software environments to test the efficiency, pros and cons of different NM.

## DESCRIPTION OF CONTENTS: PROGRAMME

PROGRAMME

1- PRINCIPLES OF NUMERICAL MATHEMATICS.
Well-Posedness and Condition Number of a Problem.
Stability of Numerical Methods.
The Floating-Point Number System.

2- ROOTFINDING OF NONLINEAR EQUATIONS.
Conditioning of a Nonlinear Equation.
The Newton-Raphson Method.
Newton's Methods for Systems of Nonlinear Equations.

3- UNCONSTRAINED OPTIMIZATION.
Necessary and Sufficient conditions for Optimality. Convexity.
Optimization Methods.

4- FINITE DIFFERENCE METHODS: INTERPOLATION, DIFFERENTIATION AND INTEGRATION.
Backward, Forward, and Central Differences.
Interpolation and Extrapolation methods.

5- NUMERICAL SOLUTIONS OF ORDINARY DIFFERENTIAL EQUATIONS (ODEs).
ODEs and Lipschitz Condition.
One Step Numerical Methods.
Zero-Stability, Convergence Analysis and Absolute Stability.
Consistency.
Numerical methods for ODEs.
Systems of ODEs.
Stiff Problems.

6- APROXIMATION THEORY.
Least-Squares Solutions
Fast Fourier Transform.

## LEARNING ACTIVITIES AND METHODOLOGY

One of the purposes of this course is to provide the mathematical foundations of numerical methods, to analyze their basic theoretical properties (stability, accuracy, computational complexity), and demonstrate their performances on examples and counterexamples which highlight their pros and cons. The primary aim is to develop algorithmic thinking emphasizing essential computational concepts. Every chapter is supplied with examples, exercises and applications of the theory developed in class. The course relies throughout on well tested numerical procedures for which we include codes and test files.

Students should write their own codes by studying and eventually rewriting the codes given by the Teacher in Aula Global. The codes written by the students should be run, tested and uploaded to Aula Global in the Computer Room classes.

Throughout the course we emphasize graphic 2D and 3D representations of solutions. Through this visual approach, students will become familiar with results at a more intuitive level, and will be able to gain insight into the behavior of numerical solutions.

## ASSESSMENT SYSTEM

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|---|---|
| **% end-of-term-examination/test:** | 50 |
| **% of continuous assessment (assigments, laboratory, practicals…):** | 50 |

The final grade will be calculated as follows:  50%  final exam score  +  50% continuous assessment score, which includes 3 computational assignments (counting 10% of the final grade each) and a

**% end-of-term-examination/test:** 50

**% of continuous assessment (assigments, laboratory, practicals…):** 50

midterm exam (counting 20%).

## BASIC BIBLIOGRAPHY


- [A] K. Atkinson Elementary Numerical Analysis, John Wiley & Sons, 2004
- [BC] A. Belegundu and T. Chandrupatla Optimization Concepts and Applications in Engineering, Cambridge University Press, Second Edition. 2011., 2011
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- [DCM] S. Dunn, A. Constantinides and P. Moghe Numerical Methods in Biomedical Engineering, Elsevier Academic Press, 2010
- [KC] D. Kincaid and E. W. Cheney Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Society , 2002
- [MF] J. H. Mathews and K. D. Fink Numerical Methods Using Matlab, 4th ed., Pearson Prentice Hall , 2004
- [QSG] A. Quarteroni, F. Saleri and P. Gervasio Scientific computing with MATLAB and Octave, Springer, 2010
- [QSS] A. Quarteroni, R. Sacco and F. Saleri Numerical Mathematics, Springer, 2007


## ADDITIONAL BIBLIOGRAPHY


- [HH] D. Higham and N. Higham Matlab Guide, Second Edition. , 2005.
- [K] C. Kelley Iterative Methods for Optimization, SIAM, 1999.
- [NW] J. Nocedal and S. J. Wright Numerical Optimization, Springer, 2006