Numerical Methods for Economy and Finance

Academic Year: (2023 / 2024) **Review date: 09/02/2024 14:22:15**

Department assigned to the subject: Mathematics Department

Coordinating teacher: BERNAL MARTINEZ, FRANCISCO MANUEL

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Linear Algebra (Year 1 - Semester 1)
Differential Calculus (Year 1 - Semester 1)
Programming (Year 1 - Semester 1)
Integral Calculus (Year 1 - Semester 2)
Numerical Methods (Year 2 - Semester 1)
Probability (Year 2 - Semester 2)
Ordinary differential equations (Year 3 - Semester 1)
Partial Differential Equations (Year 3 - Semester 2)

LEARNING OUTCOMES

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.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG1. Students are able to demonstrate knowledge and understanding of concepts in mathematics, statistics and computation and to apply them to solve problems in science and engineering with an ability for analysis and synthesis.
CG2. Students are able to formulate in mathematical language problems that arise in science, engineering, economy and other social sciences.
CG3. Students can solve computationally with the help of the most advanced computing tools mathematical models coming from applications in science, engineering, economy and other social sciences.
CG4. Students are able to show that they can analyze and interpret, with help of computer science, the solutions obtained from problems associated to real world mathematical models, discriminating the most relevant behaviours for each application.
CG5. Students can synthesize conclusions obtained from analysis of mathematical models coming from real world applications and they can communicate in verbal and written form in English language, in an clear and convincing way and with a language that is accessible to the general public.
CG6. Students can search and use bibliographic resources, in physical or digital support, as they are needed to state and solve mathematically and computationally applied problems arising in new or unknown environments or with insufficient information.
CE6. Students have shown that they know the fundamental mathematical results supporting the theory and the development of programming languages and intelligent systems.
CE7. Students are able to construct mathematical models of both discrete and continuous processes that appear in real world applications emphasizing the use of deterministic and stochastic difference

and differential equations.
CE8. Students are able to discretize mathematical models associated to real world problems using interpolation and approximation techniques, in order to solve them numerically by means of direct or iterative methods and to interpret the obtained solutions.
CE10. Students have shown that they know and understand the algorithmic procedures to design and build programs that solve mathematical problems paying special attention to performance.

RA1. Students must have acquired advanced cutting-edge knowledge and demonstrated indepth understanding of the theoretical and practical aspects of working methodology in the area of applied mathematics and computing.
RA2. Through sustained and well prepared argument and procedures, students will be able to apply their knowledge, their understanding and the capabilities to resolve problems in complex specialized professional and work areas requiring the use of creative and innovative ideas.
RA3. Students must have the capacity to gather and interpret data and information on which they base their conclusions, including where relevant and necessary, reflections on matters of a social, scientific, and ethical nature in their field of study.
RA4. Students must be able to perform in complex situations that require developing novel solutions in the academic as well as in the professional realm, within their field of study.
RA5. Students must know how to communication with all types of audiences (specialized or not) their knowledge, methodology, ideas, problems and solutions in the area of their field of study in a clear and precise way.
RA6. Students must be capable of identifying their own education and training needs in their field of study and the work or professional environment and organize their own learning with a high degree of autonomy in all types of contexts (structured or not).
RA7. Students must possess the professional maturity necessary to choose and evaluate their work objectives in a reflexive, creative, self-determined and responsible way, for the betterment of society.

DESCRIPTION OF CONTENTS: PROGRAMME

Part One: introduction to stochastic calculus

1.1 Recap of probability; characteristic functions
1.2 Law of Large Numbers & Central Limit Theorem
1.3 Brownian motion; Wiener process; Brownian bridge
1.4 Stochastic integral; Itô calculus
1.5 Stochastic differential equations; paradigmatic examples; martingales
1.6 Euler-Maruyama method; weak and strong error convergence
1.7 Advanced numerical methods for SDEs
1.8 Feynman-Kac formula

Part Two: vanilla options pricing

2.1 Financial options; arbitrage; hedging
2.2 The Black-Scholes equation; analytical solution
2.3 Numerical solution by finite differences
2.4 Numerical solution by Monte Carlo simulation; risk-neutral probability
2.5 Calibration; implied volatility
2.6 The Greeks

Part Three: advanced options pricing

3.1 Local volatility models; Heston's model
3.2 Variance reduction
3.3 Basket options
3.4 Path-dependent options
3.5 American options

Part Four: portfolio optimisation

4.1 Constrained optimisation; KKT conditions; linear & quadratic programming; duality
4.2 Bond portfolio optimisation
4.3 Markowitz's mean-variance analysis; Sharpe ratio; capital asset pricing model (CAPM)

LEARNING ACTIVITIES AND METHODOLOGY

AF1.THEORETICAL-PRACTICAL CLASSES. Knowledge and concepts students must acquire. Student receive course notes and will have basic reference texts to facilitatefollowing the classes and carrying out follow up work.Students partake in exercises to resolve practical problems and participatein workshops and an evaluation tests, all geared towards acquiring the necessary capabilities.Subjects with 6 ECTS are44 hours as a general rule/ 100% classroom instruction
AF2.TUTORING SESSIONS. Individualized attendance (individual tutoring) or in-group (group tutoring) for students with a teacher.Subjects with 6 credits have 4 hours of tutoring/ 100% on- site attendance.
AF3.STUDENT INDIVIDUAL WORK OR GROUP WORK.Subjects with 6 credits have 98 hours/0% on-site.
AF8.WORKSHOPS AND LABORATORY SESSIONS. Subjects with 3 credits have 4 hours with 100% on-site instruction. Subjects with 6 credits have 8 hours/100% on-site instruction.
MD1.THEORY CLASS. Classroom presentations by the teacher with IT and audiovisual support in which the subject`s main concepts are developed, while providing material and bibliography to complement student learning.
MD2.PRACTICAL CLASS. Resolution of practical cases and problem, posed by the teacher, and carried out individually or in a group.
MD3.TUTORING SESSIONS. Individualized attendance (individual tutoring sessions) or in-group (group tutoring sessions) for students with teacher as tutor. Subjects with 6 credits have 4 hours of tutoring/100% on-site.
MD6.LABORATORY PRACTICAL SESSIONS. Applied/experimental learning/teaching in workshops and laboratories under the tutor's supervision.

ASSESSMENT SYSTEM

% end-of-term-examination/test:	40
% of continuous assessment (assigments, laboratory, practicals…):	60

SE1.FINAL EXAM. Global assessment of knowledge, skills and capacities acquired throughout the course.The percentage of the evaluation varies for each subject between 60% and 0%.
SE2.CONTINUOUS EVALUATION. Assesses papers, projects, class presentations, debates, exercises, internships and workshops throughout the course.The percentage of the evaluation varies for each subject between 40% and 100% of the final grade.

BASIC BIBLIOGRAPHY

- Cornelis W. Oosterlee & Lech A. Grzelak Mathematical Modeling and Computation in Finance: With Exercises and Python and MATLAB Computer Codes, World Scientific Publishing Europe Ltd., 2019

- Emmanuel Gobet Monte-Carlo Methods and Stochastic Processes From Linear to Non-Linear, Chapman & Hall, 2020

- Lawrence C. Evans An Introduction to Stochastic Differential Equations, AMS American Mathematical Society, 2013

- Paolo Brandimarte Numerical methods in finance and economics: a MATLAB-based introduction, John Wiley & Sons, 2006

- Paul Wilmott, Sam Howison & Jeff Dewynne The Mathematics of Financial Derivatives: A Student Introduction, Cambridge University Press, 1995

- Peter E. Kloeden, Eckhard Platen Numerical Solution of Stochastic Differential Equations, Springer-Verlag, 1992

- Steven Shreve Stochastic Calculus for Finance Ii: Continuous-Time Models, Springer, 2013