COURSE DATA

Data Subject	
Code	34249
Name	Statistical and numerical methods
Cycle	Grade
ECTS Credits	8.0
Academic year	2022 - 2023

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	2	First term
1929 - D.D. in Physics-Chemistry	Double Degree Program Physics and Chemistry	3	Second term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	9 - Statistical and numerical methods	Obligatory
1929 - D.D. in Physics-Chemistry	3 - Tercer Curso (Obligatorio)	Obligatory

Coordination

Name	Department
BALLESTER PALLARES, FACUNDO	180 - Atomic, Molecular and Nuclear Physics
MORENO MENDEZ, JOSE FELICISIMO	345 - Earth Physics and Thermodynamics

SUMMARY

The extraction of information from **experimental data** requires the use of knowledge of probability and statistical methods that are essential for making measurements of physical magnitudes. On the other hand, a large number of problems associated with physical systems do **not have an analytical solution**, so their resolution must be approached from numerical analysis.

The fundamental objective will be to provide the student with the essential statistical methods to numerically model experimental data and to be able to approach those physical problems that lack an analytical solution or involve very high volumes of calculation.

The subject contains a strong **practical** component in which it is intended that the student acquire fluency in the programming of a **high-level language** to program algorithms and models and execute them on a computer, and become familiar with numerical concepts such as precision, rounding errors, order of convergence as well as the problems in the programming of numerical algorithms.

The elementary **descriptors** considered in the preparation of the course syllabus are the following: **Probability, probability distributions, error propagation, central limit theorem, maximum likelihood, experimental data adjustments, statistical tests, quality of adjustments, introduction to techniques from Monte Carlo. Roots of functions, linear systems, eigenvalue problems, interpolation, differentiation and numerical integration, differential equations.**

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

Knowledge of linear algebra and differential and integral calculus acquired in high school and in the subjects studied in the Physics Degree and Physics-Chemistry Double Degree from previous courses, particularly the contents of mathematical methods and statistics.
Experience in carrying out measurements and analysis of experimental data acquired in the laboratories and subjects related to experimental techniques from previous courses.
Experience in the use of computers and programming elements acquired in previous subjects. Some minimal notions in the use of MatLab is convenient.

OUTCOMES

1105 - Degree in Physics

- To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.
- Ability to collect and interpret relevant data in order to make judgements.
- Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .
- Be able to understand and master the use of the most commonly used mathematical and numerical methods.

- Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.
- Prob. solving and computer skills: be able to perform calculations independently, even when a small PC or a large computer is needed, including the development of software programmes.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.
- Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.
- Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.
- Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

LEARNING OUTCOMES

• Application of numerical analysis to scientific problems.

• Learn to process experimental data numerically.

• Know the statistical tools necessary for data analysis.

• Learn to use numerical software and scientific libraries.

• Develop the ability to program numerical algorithms and simple physical models in a high-level language, and run the corresponding programs on a computer.

DESCRIPTION OF CONTENTS

1. Numerical Methods. Solving nonlinear equations.

Introduction. Bisection Method. Newton Raphson Method.

2. Numerical Methods. Linear problems.

Linear algebra problems. LU decomposition of a matrix. Solving systems of ecuaciones. Inverse matrix. Values and eigenvectors. Jacobi method.

3. Numerical Methods. Optimization.

Minimization of a function. Simplex method. Gradient method.

4. Numerical Methods. Interpolation.

Lagrange interpolation. Divided differences. Interpolation with Splines.

5. Numerical Methods. Numerical Integration and Derivation.

Numerical derivation. Richardson extrapolation. Rules integration: Trapezoidal. Simpson, Boole. Compound rules. Romberg integration.

6. Numerical Methods. Numerical Resolution of Differential Equations.

Ordinary differential equations. Integration algorithms. Euler method. Midpoint method. Predictor corrector method. Runge-Kutta methods. Quality rules integration. Finite differences and finite elements.

7. Statistical Methods. Probability and Statistics. General concepts

Definition of probability. Random variables. Calculation of probabilities. Bayes Theorem.

8. Statistical Methods. Probability Distributions.

Probability density functions. General properties of probability distributions. Expected values. Average and variance value. Distributions of more than one variable. Binomial Distribution. Poisson distribution. Gaussian distribution. Other distributions.

9. Statistical Methods. Errors. Convergence and the Law of Large Numbers.

Linear functions of random variables. Change of variables. Error propagation. Sampling. Sample inference. Law of large numbers. Central Limit Theorem.

10. Statistical Methods. Fitting of experimental data.

Estimators. Properties of estimators. Linear functions in the parameters. Parameter estimation: maximum likelihood, least squares. Nonlinear functions in the parameters. Errors in the parameters. Time series.

11. Statistical Methods. Confidence intervals. Test of hypotheses.

Confidence intervals. Estimation of confidence intervals. Gaussian confidence levels. Limits. Test of hypothesis: Neyman Pearson. Student t and F. Goodness settings: likelihood ratio, Chi-square, Kolmogorov-Smirnov.

12. Statistical Methods. Introduction to Monte Carlo techniques.

Monte Carlo methods. Random numbers. Uniform random number generators. Sampling distributions. Inverse transformation method. Acceptance-rejection method. Monte Carlo integration.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Computer classroom practice	35,00	100
Development of individual work	30,00	0
Study and independent work	90,00	0
TOTAL	**200,00**	

TEACHING METHODOLOGY

Theoretical-practical classes: The theory/problems classes consist of teaching sessions where the topic are explained and problems are realized to reinforce the understanding by students. For each topic, students will have a collection of problems proposed for their resolution that they will solve and may expose the rest of the students in the classroom.

Sessions in the Computer Classroom: Each session in the Computer Classroom will be dedicated to a particular topic of application of the numerical and statistical methods exposed in the theory classes. Each practice will be documented by means of a script available in the Virtual Classroom, where the programming of the algorithms to be used and the exercises to be solved in the laboratory using MatLab will be explained. Practice sessions last 3 hours, and a total of 12 practice sessions will be held. The first practice session will be a general introduction to the use of MatLab.

EVALUATION

The assessment method will be the following:

1) Assessment of the theoretical contents through a written exam

Weight on the total exam rating: 50%

Minimum grade to compensate: 4/10.

If in the first call the score of this section is equal to or greater than 5, this can be saved for the second call of the same course, but not for later courses.

This assessment of the theoretical contents consists of two parts:

1.1 Written exam (with a weight of 45% of the total final grade)

On the one hand, through a written exam, the comprehension of the theoretical-conceptual aspects and the formalism of the subject will be assessed, both by means of theoretical questions and through simple conceptual and numerical questions. On the other hand, the ability to apply the formalism, through problem solving, as well as the critical ability regarding the results obtained, will be assessed. Likewise, a correct argumentation and an adequate justification will be valued.

1.2 Continuous evaluation (with a weight of 5% of the total final grade)

In this part, the exercises solved by the students throughout the course will be assessed, in particular the detailed resolution of the problem sheets proposed by the teacher, delivered by the students for evaluation, and also the oral presentation of the resolution of the problems by the students in class.

2) Assessment of the practical contents of the computer room

Weight on the total exam rating: 50%

Minimum grade to compensate: 4/10.

If in the first call the score of this section is equal to or greater than 5, this can be saved for the second call of the same course, but not for later courses.

There will be a continuous evaluation of the tasks, problems and questionnaires raised by the teacher and carried out by the students in the computer room throughout the course. The work carried out by the students during the practices will consist of the resolution of specific problems of numerical calculation and statistical methods. In these works, the student must implement and execute the codes that allow him to solve the proposed problems using Matlab on the computers in the computer room. The continuous evaluation will be based fundamentally on the reports presented by the students in digital form at the end of each practice, but if it is considered appropriate, an exam on these contents can be carried out at the end of the practice sessions.

REFERENCES

Basic

- J.H. Mathews y KD Fink. Métodos Numéricos con Matlab.Prentice Hall. Madrid 2000.
- J.D. Faires y R. Burden. Métodos Numéricos. Thompson-Paraninfo (2004).
- R.J. Barlow. A Guide to the Use of Statistical Methods in the Physical Sciences. Wiley & Sons 1989.
- Glen Cowan. Statistical Data Analysis. Oxford University Press 1998.
- C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientist, Third edition, Mc Graw-Hill International Edition.

Additional

- G. M. Phillips y P.J Taylor, Theory and applications of Numerical Analysis, Academic Press, 1994
- Press, Teukolsky, Numerical Recipes, Cambridge University Press.
- S. Brandt, Data Analysis: Statistical and Computational Methods for Scientists and Engineers, Springer 1999.
- W.T. Eadie Statistical Methods in Experimental Physics. Ed. North Holland P.C.
- F. James. Statistical Methods in Experimental Physics. World Scientific 2006.
- M.G. Kendall and S. Stuart: The Advanced Theory of Statistics. Charles Griffin & Co. 3 volumenes.