COURSE DATA

Data Subject	
Code	34249
Name	Statistical and numerical methods
Cycle	Grade
ECTS Credits	8.0
Academic year	2023 - 2024

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	2	Annual
1929 - D.D. in Physics-Chemistry	Double Degree Program Physics and Chemistry	3	First 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
ZORNOZA GOMEZ, JUAN DE DIOS	180 - Atomic, Molecular and Nuclear Physics

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 i

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 classes consist of teaching sessions where the topics are explained by the professor, while practical classes are devoted to solve exercices by the students in order to reinforce their understanding on those topics.

For each topic, students will have a collection of exercices proposed that they will solve by hand during the lessons and in the classroom. The text of the proposed exercices wil be available online in the Virtual Classroom; the text will be the same for all the students but they will have different numerical values; the answers will be introduced in the Virtual Classroom at the end of each session.

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.

For each topic, the students will have to solve exercises similars to those done in the practical classes but using MATLAB, including plots, more details in the resolution/answers, and higher precision in the numerical answers. These answers will have to be introduced in the Virtual Classroom at the end of each practice session. Furthermore, they will have to upload a pdf file with the detailed answers (with code and plots) to the Virtual Classroom at the end of each practice session.

Practice sessions last 3 hours, and a total of 12 practice sessions will be held. The first session will be a general introduction to the use of MatLab. Attendance at these sessions is compulsory, cannot be recovered and is a necessary condition for passing the course.

Exercises to be carried out outside the classroom: For each topic, a collection of problems will be available at the Virtual Classroom that the students will have to solve by their own using MATLAB.

Each collection of exercices will be a task in the Virtual Classroom which will be available after the corresponding session at the computer classrooom. For each topic, they will have to upload a pdf file with the detailed answers (with code and plots) to the Virtual Classroom.

EVALUATION

The assessment method will consist of two parts: ongoing assessment and the written exam. The weight of each of the tasks to the final grade is the following:

	Weight	**Comments**
1.1 Written exam	40	The minimum grade to compensate with 2.1+2.2 is 4/10.
1.2 Exercices to be carried out in the theory/practical classroom	10	
2.1 Exercices to be carried out in the computer classroom during the lab sessions	35	The minimum grade to compensate with 1.1+1.2 is 4/10.
2.2 Exercices to be carried at home	15	
Total	100	

The partial grades in each of the two parts of the subject (theoretical contents and practical contents) of the first call can be saved for the second call of the same course, but not for later courses.

1) Assessment of the theoretical contents

Weight on the total final grade: 50%.

Minimum grade to compensate: 4/10.

This assessment of the theoretical contents consists of two parts:

1.1 Written exam (with a weight of 40% 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 10% of the total final grade)

In this part, the exercises solved by the students throughout the course in the theory/practical classes will be assessed.

2) Assessment of the practical contents of the computer room:

Weight on the total final grade: 50%.

Minimum grade to compensate: 4/10.

In this part, the exercices solved using MATLAB during the lab sessions in the computer room and also those done at home (with the guidance of the professors, in case it is neeed).

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.