COURSE DATA

DATA SUBJECT

Code: 34249
Name: Statistical and numerical methods
Cycle: Undergraduate Studies
ECTS Credits: 8
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	2	Annual
1929 - Double Degree Program in Physics and Chemistry	Facultat de Física	3	First quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Statistical and numerical methods	COMPULSORY
1929 - Double Degree Program in Physics and Chemistry	Tercer Curso (Obligatorio)	COMPULSORY

COORDINATION

MORENO LLACER MARIA

MORENO MENDEZ JOSE FELICISIMO

ZORNOZA GOMEZ JUAN DE DIOS

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

The following prior knowledge is recommended:

- 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.

COMPETENCES / LEARNING OUTCOMES

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Ability to collect and interpret relevant data in order to make judgements.

Be able to understand and master the use of the most commonly used mathematical and numerical methods.

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.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

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.

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 .

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 be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

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 have developed the learning skills needed to undertake further study with a high degree of autonomy.

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.

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.

DESCRIPTION OF CONTENTS

1. Numerical Methods. Solving nonlinear equations.

Introduction. Bisection method. "Regula-falsi" method. Fixed-point method. Newton-Raphson method. Secant method. Quadratic interpolation methods: direct and inverse.

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 (1-dimension): golden search, parabolic interpolation and Newton's method. N-dimensionals methods: gradient method and simplex 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

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	44,00
Laboratory	36,00
Total hours	**80,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	30,00
Independent study and work	90,00
Preparation of lessons	0,00
Preparation for assessment activities	0,00
Resolution of case studies	0,00
Total hours	**120,00**

TEACHING METHODOLOGY

Theoretical-practical classes: The theory classes consist of master classes where the contents of the subject are explained by the professor, while exercices classes are devoted to solve exercices by the students in order to reinforce their understanding on those topics. Questions will be proposed (Exercices in the classroom) with conceptual questions and numerical exercises, representative of the content of the topics explained.

Sessions in the computer classroom: The practical sessions have a duration of 3 hours, and there will be a total of 12 sessions. Attendance at these sessions is compulsory, cannot be recovered and is a necessary condition for passing the course. The first session will be a general introduction to the use of MATLAB. The rest of the sessions in the computer classroom will be dedicated to a particular topic of application of the numerical and statistical methods exposed in the theory classes. In each session in the computer classroom, students will solve individually a questionnaire (Exercices in the laboratory) with exercises

representative of the content of the theory classes, including explanations, code and plots. In addition, there will be various tests (written tests, extra exercises, etc.) to encourage students' continuous work during the course.

EVALUATION

The assessment method will consist of various parts:

Part 1 - evaluation of theoretical contents
1.1 Written exam
1.2 Classroom problems (continuous evaluation)
Part 2 - evaluation of the practical contents of the computer classroom
2.1 Laboratory problems
2.2 Other activities of the practical contents

The final grade will be given by the formula: N=0.6*(grade in 1) + 0.4*(grade in 2)

Remarks:
1) The minimum grade in 1.1 to pass is 4/10
2) The minimum grade in 2.1+2.2 to pass is 4/10
3) The grade of section 1 will be the maximum between the grade in 1.1 weighted as 6/10 or the grade of 1.1 weighted as 5/10 plus the grade of 1.2 weighted as 1/10

1) Assessment of the theoretical contents

This assessment of the theoretical contents consists of two parts:

1.1 Written exam

In the Degree in Physics, there will be a partial exam of the subject in January, and the two annual calls (in May and June). If the grade for the first partial exam is less than 4/10, students will have to take the final exam. In the first call (in May), the students who passed the first partial exam will be able to choose to keep the midterm grade (from January) and take the midterm exam for the second part, or waive the January midterm grade and take the final exam. In order to average the grades of the midterms, they will have to be greater than or equal to 4/10. In the second call (in June), the theory grade from the first call will not be kept, neither partial nor final, and the entire subject will have to be examined.

In the Double Degree, there will be one exam in January and a second call in June.

Through the written exams, on the one hand, the understanding of the theoretical-conceptual aspects and the formalism of the subject will be evaluated, both through theoretical questions and through simple conceptual and numerical questions. On the other hand, the ability to apply formalism through problem solving will be assessed, as well as the critical ability regarding the results obtained. Correct argumentation

and adequate justification will be valued.

1.2 Continuous evaluation

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

2) Assessment of the practical contents of the computer room

In this part, the exercises done in the computer room during the practice sessions (and those that the students will do at home will be assessed with the help of the teaching staff if necessary during tutorial hours). The evaluation of the practical contents of the computer classroom will include additional tests to encourage the continuous work of the students during the course (written tests to assess the understanding of the exercises performed, oral questions, extra exercises, etc.).

The grades of the practical contents in the computer room in the first call may be saved for the second call of the same academic year, but not for subsequent courses.

Evidence of copying or plagiarism in the student tasks will result in failure to pass the subject and in appropriate disciplinary action being taken (13. d) of the Statute of the University Student, RD 1791/2010, of 30 December). In the event of fraudulent practices, the "Action Protocol for fraudulent practices at the University of Valencia" will be applied (ACGUV 123/2020): https://www.uv.es/sgeneral/Protocols/C83sp.pdf

REFERENCES

Basic

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- J.H. Mathews y KD Fink, Métodos Numéricos con Matlab.Prentice Hall. Madrid 2000
- M. R. Spiegel y L. J. Stephens, Estadística, McGraw-Hill, 2007

Additional

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- W. Press et al., 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.