COURSE DATA

Data Subject	
Code	34249
Name	Statistical and numerical methods
Cycle	Grade
ECTS Credits	8.0
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	2	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	9 - Statistical and numerical methods	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 to make measurements of physical quantities. On the other hand, a large number of problems associated with physical systems have no analytical solution so that its resolution must be addressed from the numerical analysis.

The main objective will be to provide students with the essential statistical methods for experimental data and numerical models to be able to address those problems without physical and analytical solution or calculation involving very high volumes.

In addition, the material contains a strong practical component in which it is intended that students acquire fluency in programming a high-level language programming algorithms and models run on a computer and be familiar with numerical concepts such as accuracy, errors rounding, order of convergence as well as problems in the programming of numerical algorithms.

The descriptors proposed in the document Curriculum Degree in Physics established to address the following topics: Probability, probability distributions, error propagation, Central Limit Theorem,

maximum likelihood, adjustments of experimental data, statistical tests, quality adjustments, introduction to Monte Carlo techniques. Roots of functions, linear systems, eigenvalue problems, interpolation, numerical differentiation and 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 of Mathematics, Mathematical Methods I and II. Experience in performing measurements and analysis of experimental data acquired in the subject Introduction to Experimental Physics. Computers and programming experience gained in the subject Informatics.

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.
-Know the necessary statistical tools for data analysis.
-Learning to program numerical algorithms in a high level language.
-Learn to use numerical and scientific software libraries.
-Develop the ability to program simple physical models and install the appropriate software on a computer.
-Learn to treat experimental data numerically.

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	85,00	0
TOTAL	**195,00**	

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: The sessions in the Computer Classroom will be dedicated to apply with MATLAB the topics of Statistical and Numerical Methods exposed in the theory classes, where the programming of the algorithms to be used and the exercises to be solved will be explained.

EVALUATION

The assessment method will be the following:

1) Assessment of the theoretical contents through a written exam: on the one hand, 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 formalism will be assessed by solving problems, as well as the critical capacity with respect to the results obtained. In both parts, a correct argumentation and an adequate justification will be assessed. Likewise, the exercises solved by the student throughout the course may be assessed.

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.

2) Assessment of the practical contents of the computer room: There will be a continuous assessment of the work done by the students to solve numerical calculation problems and statistical methods proposed throughout the course. In these works the student must implement and execute the codes that allow the resolution of the proposed problems. Likewise, an examination of these contents may be carried out.

Weight on the total exam rating: 50%. Minimum grade to compensate: 4/10.

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.

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

In case that health situation requires blended teaching, the teaching model approved by the Academic Degree Committee on July 23, 2020 will be adopted.
For lectures this model consist of 50% student attendance in the classroom, while the rest of students attend the class in streaming broadcast. Two groups will be set with alternate days attendance to the classroom in order to guarantee 50% of teaching hours attendance for all students.
The rest of the teaching activities (laboratories, computer rooms, tutorials) will have a 100% attendance.
If a total reduction in attendance is necessary, classes will be broadcast by synchronous videoconference at their regular schedule, along the period determined by the Health Authority.