26933 - Chaos and Nonlinear Dynamic Systems

Información del Plan Docente

Academic Year	2017/18
Faculty / School	100 - Facultad de Ciencias
Degree	447 - Degree in Physics
ECTS	5.0
Year	
Semester	Second semester
Subject Type	Optional
Module	---

1.General information

1.1.Introduction

By definition, non-linear systems do not fulfill the lineal superposition princi=< that is, if A and B are solution of our problem, in a nonlinear system A + B it is not a solution. These systems interest to physics and science in general because most dynamic systems are non-linear in nature and therefore more difficult to solve than the linear ones. This course aims to provide the student with basic and homogeneous training in general aspects of nonlinear dynamic systems that enable you to study complex systems in the field of physics and other related sciences such as biophysics or sociophysics for instance. It is also planned as an introduction to physics modeling and the physics of complex systems.

1.2.Recommendations to take this course

It is recommended to have studied the courses of Mathematical Analysis, Differential Equations and Computational Physics. Likewise, it is recommended a continuous follow-up of the course with attendance to the classes and interaction with the faculty of the course.

1.3.Context and importance of this course in the degree

This is an optative course that must be completed in the second semester of the third or fourth year of the degree. It wants to approach the student to the study of a number of problems in the frontier of physics that are usually alien to the core of physics studies. In this way, based on the knowledge obtained by the student along the previous semesters of the degree, the student will be able to address a large number of interesting problems in various disciplines. Such problems have not been studied previously either because of their complexity (the study of the non-linear pendulum as mechanical system for example) or because of its location outside the traditional trunk of the studies in physical (modeling of biophysical systems for example). Acquired knowledge will allow the student to approach the frontier of knowledge in the field of Statistical and Nonlinear Physics, one discipline of physics with great activity today.

1.4.Activities and key dates

Theory and problem classes are taught throughout the second semester of the Physics degree in the place and schedule established by the center in this regard.

Evaluation sessions: the continuous evaluation is carried out throughout the entire semester. The sessions of evaluation by means of a global written test are determined by the School of Sciences and published every year on their website.

2.Learning goals

2.1.Learning goals

To pass this course the student must demonstrate the following results:

- Understands the singularity and importance of nonlinear dynamic systems.
- It is capable of analyzing a non-linear dynamic system.
- Knows the fundamental bifurcations characteristic of nonlinear dynamic systems.
- Understands and quantifies the phenomenon of chaos.
- Understands the basis of the synchronization phenomenon.
- Understands the phenomenon of non-linear localization.
- Recognize and model nonlinear phenomena

2.2.Importance of learning goals

The importance of the learning achieved is basically based on two considerations. On the one hand, the transversality of the subject will introduce the student to numerous systems not only of physics, but also of biology, the chemistry or engineering likely to be addressed with the tools acquired. On the other hand the student will learn to make simple models of a diversity of natural phenomena.

We believe that the subject Chaos and Nonlinear Dynamic Systems is a fundamental subject for deepening in some of the most interesting problems in science today.

3.Aims of the course and competences

3.1.Aims of the course

Non-linear science is a cross-disciplinary discipline with implications in all areas of science and engineering. The fundamental objective of the subject is to provide the student with the basic and computational tools necessary for the study of nonlinear dynamic systems. Given a non-linear dynamic system we are interested in characterizing it properly according to its portrait of phases (fixed points, limit cycles, strange attractors ....) and study the possible bifurcations (static and dynamic phase transitions) that appear when the different parameters of interest are varied. This study will lead us to the presentation of three fundamental paradigms of the non-linear science; the phenomena of chaos, synchronization and nonlinear localization.

Along the course we will work with many different systems and in this way the second fundamental objective will be addressed: To provide to the student basic mechanisms and tools for the design of simple models of complex phenomena.

3.2.Competences

Upon passing the subject, the student will be more competent to:

- Analyze and understand nonlinear phenomena in various scientific fields.
- Master the tools of nonlinear science
- Develop and analyze non-linear dynamic models.
- Understand the paradigmatic phenomena in non-linear science: chaos, localization and synchronization.
- Simulate nonlinear dynamic systems

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4.Assessment (1st and 2nd call)

4.1.Assessment tasks (description of tasks, marking system and assessment criteria)

The marking system is established from 0 (lower park) to 10 (higher mark) points. The student needs a 5 to pass the course.

The student must demonstrate that he has achieved the anticipated learning outcomes through the following evaluation activities:

a) Continuous evaluation of student learning by solving proposed problems (topics 1 and 2) and questionnaires (topics 3, 4, 5 and 6) on the different parts of the subject. All activities will have the same weight and together contribute to the 50% of the final grade. The minimum grade to pass this evaluation should be 3.5 out of 10

b) Realization and defense of an academic work. A list of works will be provided at the beginning of the course. The defense of the work will consist of a public presentation of 10 minutes per student plus answer to the questions raised. This activity contributes 50% of the final grade. The minimum grade to pass the activity must be 3.5 out of 10.

For those approved, the final grade (**NF**) will be calculated by renormalizing the student's average grade (**NP**) for the highest average grade achieved in the group (**NPmax**):

NF = 5 * [1+ (NP-5) / (NPmax-5)] (thus if NP = 5 then NF = 5, if NP = NPmax then NF = 10).

If NPmax is less than 9 then the given formula will be adopted using NPmax equal to 9.

Overcoming the subject through a unique global test

This global test will consist of a written exam (50% of the final grade) and the evaluation of the work done and its public defense (50% of the final grade).

Students who have already defended the work are exempt from its presentation within the only global test.

5.Methodology, learning tasks, syllabus and resources

5.1.Methodological overview

- Class lessons: basic theoretical content and practical skills are presented in a combined way.
- Making of problems in group: in these sessions the student will have to face the resolution of problems in collaboration with other colleagues and under the supervision of the subject teacher.
- Simulation practices: allow the student to become familiar with the notions of computational physics that are basic in the study of nonlinear dynamic systems.
- Realization of works: the student will demonstrate that he is able to integrate the knowledge received in the resolution of a problem of nonlinear physics.

5.2.Learning tasks

The program offered to the student in order to achieve the expected results includes the following activities:

- Participatory lectures, including the realization of problems and simulations with specific software.
- Realization of a work in the context of the subject

- Remote realization of simulations of nonlinear dynamic systems using specific software to disposition of the student.

5.3.Syllabus

0 Introduction

1 One-dimensional dynamical systems. Flows in the line, bifurcations, flows in the circle.

2 Two-dimensional dynamical systems. Linear systems in the plane, phase plane, oscillations and limit cycles, bifurcations in the plane.

3 Chaos. Lorenz equations, one-dimensional maps, fractals, strange attractors.

4 Non-linear systems with many degrees of freedom. Extended chaos, pattern formation, solitons and vortices.

5 Stochastic phenomena and non-linear systems.

6 Synchronization and complex networks. Introduction to the physics of complex networks. Kuramoto model and synchronization in complex networks. Stochastic processes in networks (random walkers, congestion and epidemics)

5.4.Course planning and calendar

The calendar of the sessions will be established by the schools of Sciences and will be announced with anticipation.

5.5.Bibliography and recommended resources

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- BB Newman, M. E. J.. Networks: An Introduction. Oxford University Press. 2010
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- BB Strogatz, Steven H.. Nonlinear dynamics and chaos : with applications to physics, biology, chemistry, and engineering / Steven H. Strogatz . - 1st paperback pr. Cambridge, Massachusetts : Perseus Books, cop. 2000
- BC Barabási, Albert-Laszló. Linked : the new science of networks / Albert-László Barabási Cambridge (Massachusetts) : Perseus, cop. 2002
- BC Dorogovtsev, S.N.. Evolution of Networks: From Biological Nets to the Internet and WWW. Oxford University Press. 2003
- BC G. L. Baker and J. A. Blackburn. The pendulum: A case study in physics. Oxford University Press, 2005
- BC Gleick, James. Caos : la creación de una ciencia / James Gleick ; traducción del inglés por Juan Antonio Gutiérrez-Larraya . - [1ª ed.] Barcelona : Seix-Barral, 1988
- BC Ott, Edward. Chaos in Dynamical Systems / Edward Ott . - 1st ed. Cambridge : Cambridge University Press, 1993
- BC Pikovsky, Arkady. Synchronization : a universal concept in nonlinear sciences / Arkady Pikovsky, Michael Rosenblum and Jürgen Kurths . - 1st. pbk. ed. Cambridge [etc.] : Cambridge University Press, 2003
- BC Strogatz, Steven Henry. Sync : the emerging science of spontaneous order / Steven Strogatz . - 1st. ed. New York : Theia, cop. 2003