Subject identification

Subject	11001 - Dinamical Systems and Chaos
Credits	1.5 in-class (37.5 hours) 4.5 distance (112.5 hours) 6 totals (150 hours).
Group	Group 1, 1S
Teaching period	1st semester
Teaching language	English

Lecturers

Lecturers	Timetable for student attention					
	Starting time	Finishing time	Day	Start date	Finish date	Office
Pere Colet Rafecas	There are no defined sessions					
Manuel Alberto Matias Muriel	There are no defined sessions					

Degrees where the subject is taught

Degree	Character	Academic year	Studies
Master's Degree in Physics of Complex Systems	Optional		Postgraduate degree

Contextualisation

This is one of the compulsory courses of the Structural Module of the master of Physics of Complex Systems. It is intended to provide a solid background on dynamical systems which will be needed for the other courses of the master.

Requirements

Recommendable

It is recommended that the student has a basic knowledge on differential equations and numerical integration of differential equations (Euler and Runge-Kutta methods).

Skills

This course develops both specific and generic competences.

Specific

1. E8: To know to characterize generic behavior of dynamical systems and their instabilities..
2. E9: To know stability analysis techniques and know how to build bifurcation diagrams..
3. E10: To know to characterize chaos and know how to calculate Lyapunov exponents.
4. E11: To know how to apply dynamical systems techniques to physical, chemical, biological and social systems..

Generic

1. TG1: To be able to describe, both mathematically and physically, complex systems in different situations.
2. TG2: To acquire the capacity to develop a complete research plan covering from the bibliographic research and strategy to the conclusions..
3. TG6: To acquire high power computation skills and advanced numerical methods capabilities in applications to problems in the context of complex systems..

Content

Theme content

1. Introduction

   Phase Space, Existence and unicity of trajectories, Liouville theorem, Hamiltonian vs dissipative systems.

2. One dimensional flows

   Geometric representation. Fixed points. Potential representation. Stability analysis. Saddle-node bifurcation. Transcritical bifurcation. Pitchfork bifurcation. Normal forms. Bifurcation diagrams. Structural stability. Imperfect bifurcations and catastrophes.

3. Two dimensional flows

   Phase portraits. Fixed points. Stability. Forced damped oscillators. Limit Cycles. Index theory. Hopf bifurcation. Gradient systems. Lyapunov functions. Poincaré Bendixson theorem. Liénard Systems. Van Der Pol oscillator. Relaxation oscillations. Weakly nonlinear oscillators. Multiple time scale analysis.

4. One dimensional maps. Chaos

   Logistic map. Fixed points. Periodic solutions. Chaos. Lyapunov exponents. Routes to chaos. Universality. Feigenbaum’s renormalization theory.

5. Three dimensional flows

   Lorenz model. Chaos. Strange attractors. Poincare map. Lorenz map. Calculation of Lyapunov exponents.

6. Fractals

   Cantor set. Self-similarity. Dimension of self-similar fractals. Box counting dimension. Correlation dimension. Generalized dimensions D_q.

7. Non-linear time series analysis

   Poincaré section. Fourier characterization. Embedding methods.

8. Excitability

   Biological motivation. Active rotator. Fizhugh-Nagumo.

9. Entrainment
   Circle map. 1:1 frequency locking. Rational lockings. Arnold tongues. Devil's staircase.
10. Syncronization of oscillators
    Weakly coupled oscillators. Reduction to phase dynamics. Synchronization. Landau-Stuart oscillators. Oscillator death. Kuramoto model. Diversity. Order Parameter. Self-consistent solution.
11. Delayed systems
    Mackey-Glass model. Fixed points. Stability analysis and its numerical evaluation.

Teaching methodology

In-class work activities

Modality	Name	Typ.Gr.	Description
Theory classes	Theory classes	Large group (G)	Lectures explaining the theoretical concepts given by the professor.
Practical classes	Practical sessions	Large group (G)	Resolution of practical examples and questions.
Laboratory classes	Lab sessions	Medium group (M)	This activity aims at the visualization of the nonlinear phenomena in real experimental systems. Experiments will be performed in mechanical, electronic or chemical systems.
Assessment	Oral presentation	Large group (G)	Each student will be given an individualized assignment that covers several of the topics of the course. Besides a written report, the student has to give an oral presentation to the whole class.

Distance education work activities

Modality	Name	Description
Individual self-study	Exercises	The student has to solve exercises assigned and present the solutions in written form.
Individual self-study	Realization of the assignment	The student must solve the individual assignment, prepare a report and organize an oral presentation.
Individual self-study	Study and understanding theoretical concepts	This activity aims at the understanding of the theoretical concepts and techniques explained in the lectures

Riscs especifics i mesures de protecció

Les activitats d'aprenentatge d'aquesta assignatura no comporten riscs específics per a la seguretat i salut de l'alumnat i, per tant, no cal adoptar mesures de protecció especials.

Workload estimate

Modality	Name	Hours	ECTS	%
In-class work activities		**37.5**	**1.5**	**25**
Theory classes	Theory classes	26	1.04	17.33
Practical classes	Practical sessions	6	0.24	4
Laboratory classes	Lab sessions	5	0.2	3.33
Assessment	Oral presentation	0.5	0.02	0.33
Distance education work activities		**112.5**	**4.5**	**75**
Individual self-study	Exercises	40	1.6	26.67
Individual self-study	Realization of the assignment	40	1.6	26.67
Individual self-study	Study and understanding theoretical concepts	32.5	1.3	21.67
	Total	**150**	**6**	**100**

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Campus Extens platform.

Student learning assessment

Oral presentation

Modality	Assessment
Technique	Papers and projects **(Non-recoverable)**
Description	Each student will be given an individualized assignment that covers several of the topics of the course. Besides a written report, the student has to give an oral presentation to the whole class.
Assessment criteria	Accuracy and quality of the work as well as the clarity in the oral exposition.

Percentage of final qualification: 20% following path A

Exercises

Modality	Individual self-study
Technique	Papers and projects **(Non-recoverable)**
Description	The student has to solve exercises assigned and present the solutions in written form.
Assessment criteria	Accuracy of the answers. Clarity and quality of the explanations.

Percentage of final qualification: 50% following path A

Realization of the assignment

Modality	Individual self-study
Technique	Papers and projects **(Non-recoverable)**
Description	The student must solve the individual assignment, prepare a report and organize an oral presentation.
Assessment criteria	Suitability of the introduction and motivation. Accuracy of the work. Clarity of the ideas and explanations. Relevance of the conclusions. Quality of the written report.

Percentage of final qualification: 30% following path A

Resources, bibliography and additional documentation

Basic bibliography

S.H. Strogatz, "Nonlinear Dynamics and chaos", Addison Wesley 1994 / Westview Press 2000.
E. Ott, "Chaos in Dynamical Systems", Cambridge University Press, 2nd edition, 2002.

Complementary bibliography

T. Schreiber, "Interdisciplinary application of nonlinear time series methods", Physics Reports vol. 308, p. 1-64 (1999) [mainly for topic 7].
J.D. Murray, "Mathematical biology", 3rd edition, Springer, 2003 [mainly for topic 8].
A. Pikovsky, M. Rosenblum, J. Kurths, “Synchronization: A universal concept in nonlinear sciences”, Cambridge University Press, 2001 [mainly for topics 9-10].
S.H. Strogatz, "From Kuramoto to Crawford", Physica D vol. 143, p. 1 (2000) [mainly for topic 10].
T. Erneux, "Applied Delay Differential Equations", Springer, 2009. [mainly for topic 11].

Other resources