UAB
Universitat Autònoma de Barcelona

Dynamical Systems and Complexity

Code: 45559
ECTS Credits: 6

2025/2026

Degree	Type	Year
Modelización para la Ciencia y la Ingeniería / Modelling for Science and Engineering	OP	1

Contact

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

Students must have mathematical skills at a graduate level of a scientific degree.

Objectives and Contextualisation

The course aims to develop the students' ability to systematically analyze deterministic nonlinear dynamical models and to elaborate mathematical models of real systems.

Learning Outcomes

1. CA09 (Competence) Devise models based on dynamical systems and complex systems to solve specific practical problems.
2. CA09 (Competence) Devise models based on dynamical systems and complex systems to solve specific practical problems.
3. CA10 (Competence) Communicate to an expert audience the results obtained from the analysis of models based on dynamic and complex systems incorporating ethical, sustainability and gender equality criteria.
4. CA10 (Competence) Communicate to an expert audience the results obtained from the analysis of models based on dynamic and complex systems incorporating ethical, sustainability and gender equality criteria.

5. CA10 (Competence) Communicate to an expert audience the results obtained from the analysis of models based on dynamic and complex systems incorporating ethical, sustainability and gender equality criteria.
6. CA11 (Competence) Assess, using specific metrics and mathematical tools, the level of complexity of a set of data obtained through experimentation and/or observations.
7. KA09 (Knowledge) Recognise the main analysis techniques to study dynamical systems, as well as the theoretical scope of application of each of them.
8. KA09 (Knowledge) Recognise the main analysis techniques to study dynamical systems, as well as the theoretical scope of application of each of them.
9. KA09 (Knowledge) Recognise the main analysis techniques to study dynamical systems, as well as the theoretical scope of application of each of them.
10. KA10 (Knowledge) Recognise the different criteria that can be used to quantify and/or measure the complexity of a system.
11. KA10 (Knowledge) Recognise the different criteria that can be used to quantify and/or measure the complexity of a system.
12. SA09 (Skill) Formulate dynamical systems and complex models capable of capturing essential dynamic features of specific applications.
13. SA09 (Skill) Formulate dynamical systems and complex models capable of capturing essential dynamic features of specific applications.
14. SA09 (Skill) Formulate dynamical systems and complex models capable of capturing essential dynamic features of specific applications.
15. SA10 (Skill) Solve, either analytically or computationally, complex dynamic models using the appropriate mathematical tools for each situation.
16. SA10 (Skill) Solve, either analytically or computationally, complex dynamic models using the appropriate mathematical tools for each situation.
17. SA11 (Skill) Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.
18. SA11 (Skill) Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.
19. SA11 (Skill) Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.
20. SA11 (Skill) Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.

Content

1. Introduction to Dynamical Systems

Types and characteristic properties. Related concepts.

2. One-Dimensional Discrete Dynamical Systems

Graphical and analytical study. Fixed points. Linear stability. Bifurcations. The logistic map.

3. Two-Dimensional Dynamical Systems

Classification of linear systems. Phase portrait. Limit cycles. Bifurcations. Biological models.

4. Chaotic Dynamical Behavior

Deterministic chaos. Definition. Examples.

5. Introduction to numerical methods

Numerical methods: error sources. Euler and Runge-Kutta methods.

6. Spatio-temporal dynamics

Metapopulation models. Coupled map lattices. Cellular autonomy. Reaction-diffusion equations.

7. Complexity

Systems with novel organized topology. Basic elements of complex systems. Emergent behaviors. Case studies. Measures of complexity.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Theory and problem-solving classes	38	1.52	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11, CA09
Type: Supervised			
Problem sets and projects	40	1.6	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11, CA09
Type: Autonomous			
Independent study	69	2.76	CA09, CA11, KA09, KA10, SA09, SA10, SA11, CA09

The methodology is based on lectures that include some practical exercises (either written or computational). Most of the exercises will be solved and submitted periodically by students through the Virtual Campus. Afterwards, any doubts regarding these exercises will be discussed in class.

Note: 15 minutes of one class session, within the schedule established by the department or degree program, will be reserved for students to complete surveys evaluating the teaching performance and the course/module.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam	25%	3	0.12	CA09, CA11, KA09, KA10, SA09, SA10
Projects and worked-out exercises	75%	0	0	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11

Continuous Assessment

Grades will be based on:

- Submission of solved problems, simulations, reports, and presentations, which will account for 75% of the final grade.

- A written exam, which will account for 25% of the final grade.

To pass the course, the weighted average of both components must be greater than 5 (out of 10).

Single Assessment

Students who choose the single assessment modality must take a final exam, which will consist of problem-solving and some theoretical questions. After the exam, they must also submit all exercises and reports related to the coursework.

The final grade and the passing threshold are the same as in the continuous assessment.

For both types of assessment (continuous and single), if the final grade is below 5, the student will have a second opportunity to pass the course through a resit exam (worth 25%) and the submission of exercises and reports (worth 75%).

Bibliography

- S.H. Strogatz. Nonlinear Dynamics and Chaos. Second Edition. Perseus Books, Westview Press, Boulder, 2014.

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- S. Parker , Leon O. Chua. Practical Numerical Algorithms for Chaotic Systems (1989).

- B.C. Goodwin, How the Leopard Changed Its Spots: Evolution of Complexity. Prentice Hall, 1994.

– Hanski, I. Metapopulation Ecology Oxford University Press. 1999.

– J.D. Murray. Mathematical Biology I: An introduction. Interdisciplinary Applied Mathematics 2002

– W. A. Strauss, Partial Differential Equations: An Introduction, John Wiley & Sons, 1992.

– K. Kaneko. Theory and Applications of Coupled Map Lattices (Nonlinear Science: Theory and Applications) 1st Edition, 1993

– A. Ilachinski. Cellular Automata: A Discrete Universe, 2001

– U. Dieckmann, R. Law, J.A.J. Metz. The Geometry of Ecological Interactions: Simplifying Spatial Complexity: 1 (Cambridge Studies in Adaptive Dynamics, Series Number 1), 2000

- R. Clark Robinson, An introduction to Dynamical Systems: Continuous and Discrete, Pure and Applied undergraduate texts, American Mathematical Society, 2012

- Robert L. Devaney, An introduction to Chaotic Dynamical Systems, Westview Press, 2003

- Stefan Thurner, Peter Klimek, Rudolf Hanel, Introduction to the Theory of Complex Systems, Oxford University Press, 2018

- Introduction to Complexity (online). Complexity Explorer, Santa Fe (https://www.complexityexplorer.org/courses/185-introduction-to-complexity#gsc.tab=0)

Software

There is no specific software for the subject.

Groups and Languages

Please note that this information is provisional until 30 November 2025. You can check it through this link. To consult the language you will need to enter the CODE of the subject.

Name	Group	Language	Semester	Turn
(TEm) Theory (master)	1	English	first semester	afternoon