ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

595040073 - Dynamical Systems

DEGREE PROGRAMME

59SC - Grado En Ingenieria De Sistemas De Telecomunicacion

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 2

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	595040073 - Dynamical Systems
No of credits	3 ECTS
Type	Optional
Academic year ot the programme	Third year
Semester of tuition	Semester 6
Tuition period	February-June
Tuition languages	English
Degree programme	59SC - Grado en Ingenieria de Sistemas de Telecomunicacion
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Rafael Jose Hernandez Heredero (Subject coordinator)		rafael.hernandez.heredero@upm.es	- -

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- Calculo I

- Algebra Lineal

- Calculo Ii

3.2. Other recommended learning outcomes

- This course cannot be followed and passed without a previous knowledge of Calculus I, Calculus II and Linear Algebra. They are not marked in this guide as compulsory prerequisites only because of administrative constraints.

4. Skills and learning outcomes *

4.1. Skills to be learned

CE B1 - Capacidad para la resolución de los problemas matemáticos que puedan plantearse en la ingeniería. Aptitud para aplicar los conocimientos sobre: álgebra lineal; geometría; geometría diferencial; cálculo diferencial e integral; ecuaciones diferenciales y en derivadas parciales; métodos numéricos; algorítmica numérica; estadística y optimización.

CG 02 - Capacidad de búsqueda y selección de información, de razonamiento crítico y de elaboración y defensa de argumentos dentro del área.

CG 03 - Capacidad para expresarse correctamente de forma oral y escrita y transmitir información mediante documentos y exposiciones en público.

CG 04 - Capacidad de abstracción, de análisis y de síntesis y de resolución de problemas.

CG 11 - Habilidades para la utilización de las Tecnologías de la Información y las Comunicaciones.

CG 12 - Habilidad para las relaciones interpersonales y el trabajo en un contexto nacional e internacional, con capacidad para expresarse de forma oral y escrita en lengua inglesa.

CG 13 - Habilidades de aprendizaje con un alto grado de autonomía.

4.2. Learning outcomes

RA1168 - Conocer la tipología del espacio de fases de sistemas lineales multidimensionales. Analizar y clasificar sistemas concretos de ese tipo.

RA1166 - Analizar sistemas modelados por una ecuación diferencial escalar de primer orden, determinando puntos estacionarios y su estabilidad. Describir analítica o numéricamente bifurcaciones producidas en ese tipo de sistemas que dependen de parámetros.

RA1174 - Familiarizarse con la teoría del caos y aprender a predecir y reconocer cuándo se presenta este fenómeno: el sistema de Lorenz.

RA1172 - Reconocer los tipos básicos de bifurcación: silla-nodo, tridente, Hopf ...

RA1175 - Analizar ejemplos de sistemas caóticos en tecnología: los fenómenos homoclínicos y el circuito de Chua.

RA1170 - Clasificar los equilibrios linealizando el sistema a su alrededor.

RA1167 - Describir el espacio de fases de sistemas planos lineales. Conocer la clasificación algebraica y topológica de dichos sistemas.

RA1176 - Utilizar sistemas de cálculo numérico y simbólico por ordenador, tales como Maple, Matlab, Mathematica, Python, etc, para analizar sistemas dinámicos de dimensión finita.

RA1171 - Utilizar técnicas globales de análisis de sistemas no lineales. Estimar la existencia de órbitas periódicas y aplicar el teorema de Poicaré-Bendixson.

RA1169 - Reconocer los sistemas no lineales y encontrar sus equilibrios analítica o numéricamente.

RA1173 - Aprender a aplicar la teoría a sistemas dinámicos en el área de la electrónica: ecuación de van der Pol.

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course is an introduction to the theory of differential equations from the point of view the theory of dynamical systems. We will treat some techniques from the qualitative analysis of equations and applications in electronics and science.

5.2. Syllabus

1. FIRST-ORDER ORDINARY DIFFERENTIAL EQUATIONS
2. PLANAR LINEAR SYSTEMS
3. HIGHER-DIMENSIONAL LINEAR SYSTEMS
4. INTRODUCTION TO NONLINEAR SYSTEMS
5. GLOBAL NONLINEAR TECHNIQUES
6. APPLICATIONS
   - 6.1. Circuit theory
   - 6.2. Biology and epidemiology
7. CHAOS: THE LORENZ SYSTEM
   - 7.1. The Lorenz attractor
   - 7.2. A model for the Lorenz attractor
8. HOMOCLINIC PHENOMENA: CHUA?S CIRCUIT
   - 8.1. Homoclinic phenomena
   - 8.2. The horseshoe map
   - 8.3. Chua's circuit

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Chapter 1** Duration: 02:00 Lecture			**Self-study during the whole semester.** Other assessment Continuous assessment and final examination Not Presential Duration: 25:00
2	**Chapter 2** Duration: 02:00 Lecture			
3		**Chapter 2** Duration: 02:00 Laboratory assignments		**Homework 1** Individual presentation Continuous assessment Not Presential Duration: 00:00
4	**Chapter 2** Duration: 02:00 Lecture			
5	**Chapter 3** Duration: 02:00 Lecture			**Homework 2** Individual presentation Continuous assessment Not Presential Duration: 00:00
6	**Chapter 4** Duration: 02:00 Lecture			
7		**Chapter 4** Duration: 02:00 Laboratory assignments		
8	**Chapter 4** Duration: 02:00 Lecture			**Homework 3** Individual presentation Continuous assessment Not Presential Duration: 00:00
9	**Chapter 5** Duration: 02:00 Lecture			
10	**Chapter 5** Duration: 02:00 Lecture			**Homework 4** Individual presentation Continuous assessment Not Presential Duration: 00:00

11	**Chapter 6** Duration: 02:00 Lecture			
12	**Chapter 6** Duration: 01:40 Lecture			**Group projects recitation** Group presentation Continuous assessment Presential Duration: 00:20
13	**Chapter 7** Duration: 02:00 Lecture			**Homework 5** Individual presentation Continuous assessment Not Presential Duration: 00:00
14		**Chapters 6,7, y 8** Duration: 02:00 Laboratory assignments		
15				**Homework 6** Individual presentation Continuous assessment Not Presential Duration: 00:00
16				
17				**Global exam** Written test Continuous assessment Presential Duration: 03:00 **Final exam** Written test Final examination Presential Duration: 03:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Self-study during the whole semester.	Other assessment	No Presential	25:00	%	5 / 10	CE B1 CG 02 CG 03 CG 04 CG 11 CG 12 CG 13
3	Homework 1	Individual presentation	No Presential	00:00	7%	5 / 10	
5	Homework 2	Individual presentation	No Presential	00:00	7%	5 / 10	
8	Homework 3	Individual presentation	No Presential	00:00	7%	5 / 10	
10	Homework 4	Individual presentation	No Presential	00:00	7%	5 / 10	
12	Group projects recitation	Group presentation	Face-to-face	00:20	8%	5 / 10	
13	Homework 5	Individual presentation	No Presential	00:00	7%	5 / 10	
15	Homework 6	Individual presentation	No Presential	00:00	7%	5 / 10	
17	Global exam	Written test	Face-to-face	03:00	50%	5 / 10	

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Self-study during the whole semester.	Other assessment	No Presential	25:00	%	5 / 10	CE B1 CG 02 CG 03 CG 04 CG 11 CG 12 CG 13

17	Final exam	Written test	Face-to-face	03:00	100%	5 / 10	

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Referred (re-sit or extraordinary) examination	Written test	Face-to-face	03:00	100%	5 / 10	CE B1 CG 02 CG 03 CG 04 CG 11 CG 13

7.2. Assessment criteria

There are two categories of graded items:

- Problem solving, group projects and lab activities: 50% of the total grade.

- Final exam: the remaining 50%.

If the grading of the total exam results in a higher mark than the average between activities and exam, the final grade will be that of the exam. That is, the grade will be the result of applying the following formula:

Total grade=Max((activities+exam)/2, exam)

where both "activities" and "exam" are marked from 0 to 10 points. To pass the course, a total grade of 5 or more, and a minimum mark of 3 points in the final exam are required.

The extraordinary exam (in June/July) will allow to pass the course if a grade of 5 over 10 or more is obtained. The total grade will be that of the extraordinary exam.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Python, Julia, Octave	Equipment	We will work with some of these three frameworks. They can be installed in the student computer and will be installed in the Math LAB computers.
Hirsch M., Smale S., Devaney R. Differential equations, dynamical systems and an introduction to chaos (Elsevier, 2004)	Bibliography	The main textbook of the course
P. Glendinning. Stability, instability ad chaos: an introduction to the theory of nonlinear differential equations. Cambridge University Press 1994.	Bibliography	
Maia Matcheva. An introduction to Mathematical Epidemiology. Texts in Applied Mathematics. Springer (2010)	Bibliography	

9. Other information

9.1. Other information about the subject

Contribution to UN's Sustainable Development Goals (SDGs)

The course is an introduction to the theory and language of dynamical systems. Dynamical systems are a fundamental mathematical framework for modeling any process, let it be scientific, technical, in biology, ecology, health sciences, economy, climate theory, social sciences, transportation, etc. Thus, it is essential for the quantitative study of any subject whose sustainability must be increased. It is probably impossible to find a SDG to which the subject of this course does not contribute. Being more precise, the course contributes at least to the following SDGs.

SDG 4. Quality Education

4.4 Substantially increase the number of youth and adults who have relevant skills

4.6 Ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy

4.7 Ensure that all learners acquire the knowledge and skills needed to promote sustainable development

SDG 3. Health and well-being

3.3 End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases

3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases

SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.4 Upgrade infrastructure and retrofit industries to make them sustainable

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors

SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable

11.2 Provide access to safe, affordable, accessible and sustainable transport systems for all

SDG 13. Combat climate change and its impacts

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters

13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

SDG 14. Sustainably use the oceans, seas and marine resources

14.2 Sustainably manage and protect marine and coastal ecosystems

SDG 15. Sustainable use of terrestrial ecosystems

15.1 Ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services