

COURSE OFFERED

Name of the course	Polish	Chaos i dynamika nieliniowa
	English	Chaos and Nonlinear Dynamics

1 LOCATION OF THE COURSE WITHIN THE EDUCATION SYSTEM

1.1. Section ¹	Section of Exact and Natural Sciences
1.2. Discipline ²	Physical Sciences
1.3. Type of education	Full-time
1.4. Level of education	Doctoral School (PQF Level 8)
1.5. Person preparing the course description	prof. dr hab. Francesco Giacosa
1.6. Contact	fgiacosa@ujk.edu.pl

2 GENERAL CHARACTERISTICS OF THE COURSE

2.1. Type of course ³	Specialised subject in the discipline (elective)
2.2. Language of the course	English

3 DETAILED CHARACTERISTICS OF THE COURSE

3.1. Type of classes ⁴		Lecture (L)
3.2. Number of hours ⁵		15 hours of lectures
3.3. Location of classes		Classroom at Jan Kochanowski University in Kielce
3.4. Type of assessment		Graded pass based on an oral assessment with problem-solving tasks
3.5. Didactic methods		Problem-based lectures, analytical derivations and numerical demonstrations; guided discussion, worked examples and independent reading
3.6. Literature	basic	1. D. Acheson, From Calculus to Chaos: An Introduction to Dynamics, Oxford University Press, 1997. 2. K. T. Alligood, T. D. Sauer and J. A. Yorke, Chaos: An Introduction to Dynamical Systems, Springer, 1996.
	supplementary	C. Barenghi, Introduction to Chaos: Theoretical and Numerical Methods, lecture notes.

¹ Sections: Humanities; Social Sciences; Exact and Natural Sciences; Medical and Health Sciences; Arts.

² Discipline as specified in the curriculum of the Doctoral School.

³ General subjects; general subjects in the discipline; specialised subjects in the discipline.

⁴ Classes, lecture or seminar.

⁵ Consistent with the curriculum of the Doctoral School of Jan Kochanowski University in Kielce.

4 OBJECTIVES SYLLABUS CONTENT AND INTENDED LEARNING OUTCOMES

4.1. Course objectives (lecture)

C01 Explain the theoretical foundations of nonlinear dynamics and deterministic chaos.

C02 Analyse fixed points, stability, oscillations and chaos using analytical and numerical methods.

C03 Develop independent problem-solving skills and assess the limits of model-based prediction.

4.2. Syllabus content (15 hours in total)

1. Flows on the line: one-dimensional differential equations, solutions and interpretation in physics and the natural sciences. (1 h)
2. Fixed points and their classification; stability of solutions and qualitative analysis of one-dimensional flows. (1 h)
3. An example from quantum field theory: running coupling constants, renormalisation-group flows and fixed points. (1 h)
4. Two-dimensional flows: phase portraits, linearisation, fixed points, attractors and Lyapunov stability. (2 h)
5. Models in physics, biology and chemistry: population dynamics, Lotka–Volterra equations and chemical reactions. (1 h)
6. Limit cycles and bifurcations; oscillations in physical, biological and chemical systems. (1 h)
7. Three-dimensional systems and the emergence of chaos; the Lorenz system and selected physical and Earth-science examples. (2 h)
8. Lyapunov exponents: separation of nearby trajectories, sensitivity to initial conditions and interpretation across the natural sciences. (2 h)
9. Lagrangian and Hamiltonian formulations and their relation to nonlinear differential equations and chaotic dynamics. (1 h)
10. Deterministic chaos and simple numerical examples: the logistic map, numerical integration of nonlinear equations and comparison of nearby trajectories. (2 h)
11. Strange attractors and applications of nonlinear dynamics; weather forecasting, climate dynamics and limits of predictability. (1 h)

4.3 SUBJECT LEARNING OUTCOMES

Learning outcome	A doctoral student who has passed the course	Reference to Doctoral School learning outcomes
In the area of KNOWLEDGE		
W01	Explains the foundations and selected developments of nonlinear dynamics, including fixed points, stability, bifurcations, Lyapunov exponents, chaos and strange attractors.	SD_W01 SD_W02
W02	Identifies the limits of predictability in chaotic systems and their implications for nonlinear physics, weather forecasting and climate dynamics.	SD_W07
In the area of SKILLS		
U01	Formulates nonlinear models and uses differential equations, phase portraits and analytical or numerical tools to classify fixed points, assess stability and evaluate chaotic behaviour and model assumptions.	SD_U01 SD_U03
U02	Uses scientific literature and explains nonlinear dynamics and chaos in English.	SD_U07
In the area of SOCIAL COMPETENCE		
K01	Recognises the value of physical and mathematical knowledge and reliable sources in analysing nonlinear systems.	SD_K02
K02	Shows initiative in choosing models, analytical or numerical tools and sources for independently investigating a nonlinear dynamical system.	SD_K04

4.4 METHODS OF ASSESSMENT OF THE INTENDED LEARNING OUTCOMES

SUBJECT LEARNING OUTCOMES	METHOD OF ASSESSMENT (+ / -)																				
	Oral / written exam			Test (oral assessment)			Project			Activity in class			Own work			Group work			Other		
	Type of classes			Type of classes			Type of classes			Type of classes			Type of classes			Type of classes			Type of classes		
	L	C	S	L	C	S	L	C	S	L	C	S	L	C	S	L	C	S	L	C	S
W01	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
W02	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
U01	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
U02	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
K01	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
K02	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-

L = lecture; C = classes; S = seminar. + = method used; - = method not used.

The oral assessment covers conceptual questions and short analytical or numerical problem-solving tasks, including fixed-point classification, stability, phase portraits, Lyapunov exponents and interpretation of chaotic behaviour. English communication is assessed throughout. Class discussion and independently prepared tasks verify the recognition of the value of knowledge and initiative in selecting models, methods and sources.

4.5 CRITERIA OF ASSESSMENT OF THE INTENDED LEARNING OUTCOMES

Form of classes	Grade	Criterion of assessment
Lecture (L)	3.0	51-60% of the maximum points in the final oral assessment, including conceptual questions and problem-solving tasks.
	3.5	61-70% of the maximum points in the final oral assessment, including conceptual questions and problem-solving tasks.
	4.0	71-80% of the maximum points in the final oral assessment, including conceptual questions and problem-solving tasks.
	4.5	81-90% of the maximum points in the final oral assessment, including conceptual questions and problem-solving tasks.
	5.0	91-100% of the maximum points in the final oral assessment, including conceptual questions and problem-solving tasks.

Grade 2.0 (fail): fewer than 51% of the maximum points.

Accepted for implementation

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(date and signature of the lecturer)