BACHELOR 'S PROGRAMME
3rd YEAR OF STUDY, 1st SEMESTER

COURSE TITLE	INTRODUCTION IN PHYSICS OF COMPLEX SYSTEMS
COURSE CODE	
COURSE TYPE	full attendance
COURSE LEVEL	1st cycle (bachelor's degree)
YEAR OF STUDY, SEMESTER	3rd year of study, 1st semester
NUMBER OF ECTS CREDITS	4
NUMBER OF HOURS PER WEEK	4 (2 lecture hours + 2 seminar hours)
NAME OF LECTURE HOLDER	Assoc. prof. Dan DIMITRIU
NAME OF SEMINAR HOLDER	Assoc. prof. Dan DIMITRIU
PREREQUISITES	Advanced level of English

A GENERAL AND COURSE-SPECIFIC COMPETENCES

General competences:

→ Elaboration of a speciality or licence work, respecting the objectives, proposed deadlines and norms of professional ethics

→ Realization of a project / team activity and identification of specific professional roles

→ Elaboration, drafting and presentation in Romanian and / or in a language of international circulation of a speciality work on a current topic in the field

Course-specific competences:

→ Description of physical systems using specific theories and tools (experimental and theoretical models, algorithms, schemes, etc.)

→ Explanation and interpretation of physical phenomena by formulating assumptions and operationalizing key concepts and proper use of laboratory equipment

→ Make of necessary connections to use physical phenomena, using basic knowledge from close domains (Chemistry, Biology, etc.)

→ Making connections between knowledge of Physics and of other domains (Chemistry, Biology, Informatics, etc.)

→ Responsible performing independent work tasks and interdisciplinary approach of topics

B LEARNING OUTCOMES

At the successful finalization of this course, the students will be able to:

- Analyze different physical phenomena leading to similar behaviors of different complex systems;
- Understand the self-assembling mechanisms of self-organized structures which appear in different complex systems;
- Use the current methods of study of complex systems;
- Formulate hypotheses and models on the obtained experimental research results
- Critically analyse the obtained results by using the known models/theories
- Explain and interpret physical phenomena and operate with the key concepts based on the proper using of the experimental results

C LECTURE CONTENT

Main characteristics of complex systems
Qualitative changes in the dynamics of complex systems. Bifurcations
Negative differential resistance. Hysteresis. Non-equilibrium phase transitions
Physical models of complex systems (logistic map, Turing model, the Brusselator, Lorenz model, Rössler model, Duffing oscillator, van der Pol oscillator)
Scaling. Power laws. Self-similarity. Fractals
Self-organization. Symmetry breaking. Spatial, temporal and spatio-temporal self-organized structures.
Chaos. Routes to chaos. Quantities for chaotic states characterization. Chaos control
Networks. Measures on networks. Functional networks. Dynamics on and of networks
Introduction in econophysics, sociophysics and psychophysics

D RECOMMENDED READING FOR LECTURES

1. [1] A. H. Nayfeh, B. Balachandran – Applied Nonlinear Dynamics – Analytical, Computational, and Experimental Methods, Wiley-VCH, Weinheim, 2004;
2. [2] G. Nicolis, C. Nicolis – Foundations of Complex Systems. Emergence, Information and Prediction, 2nd Edition, World Scientific, Singapore, 2012;
3. [3] S. Thurner, R. Hanel, P. Klimek – Introduction to the Theory of Complex Systems, Oxford University Press, Oxford, 2018;

4. [4] R. B. Northrop – Introduction to Complexity and Complex Systems, CRC Press, Taylor & Francis Group, Boca Raton, FL, 2011.
5. [1] H. G. Schuster, W. Just – Deterministic chaos. An Introduction, 4th ed., Wiley-VCH, Weinheim, 2005;
6. [2] K. Mainzer – Thinking in Complexity. The Computational Dynamics of Matter, Mind, and Mankind, 5th Edition, Springer, Berlin, 2007;
7. [3] H. Haken – Information and Self-Organization. A Macroscopic Approach to Complex Systems, 3rd Edition, Springer, Berlin, 2010;
8. [4] I. Zelinka, A. Sanayei, H. Zenil, O. E. Rössler (Eds.) – How Nature Works. Complexity in Interdisciplinary Research and Applications, Springer, Cham, 2014;
9. [5] R. N. Mantegna, H. Eugene Stanley – An Introduction to Econophysics. Correlations and Complexity in Finance, Cambridge University Press, Cambridge, 2004;
10. [6] S. Galam – Sociophysics. A Physicist's Modeling of Psycho-political Phenomena, Springer, New York, 2012;
11. [7] F. A. A. Kingdom, N. Prins – Psychophysics. A practical Introduction, 2nd Edition, Academic Press – Elsevier, London, 2016;
12. [8] A. L. Barabási – Network Science, Cambridge University Press, Cambridge, 2016.

E	SEMINAR / LABORATORY CONTENT
	Analysis of negative differential resistance and hysteresis in plasma Physical models of complex systems Self-organized structures in plasma: fireball, multiple double layers Rayleigh-Bénard convection Experimental analysis of some scenarios of transition to chaos in plasma (by cascade of sub-harmonic bifurcations, by type I intermittency, Feigenbaum scenario) Analysis of uncorrelated dynamics of some complex space charge structures in plasma. Flicker noise Analysis of chaotic time series with specialized software Chua chaotic circuit. Control of chaos. Synchronization of chaotic circuits. Chaos-based communication Control of chaos in plasma by using external circuit elements Analysis of time series from physiology (EKG and EEG) Analysis of time series from economy and sociology
F	RECOMMENDED READING FOR SEMINARS
	[1] A. H. Nayfeh, B. Balachandran – Applied Nonlinear Dynamics – Analytical, Computational, and Experimental Methods, Wiley-VCH, Weinheim, 2004; [2] W.-H. Steeb – The Nonlinear Workbook, 4th ed., World Scientific, Singapore, 2008; [3] H. J. Korsch, H.-J. Jodl, T. Hartmann – Chaos – A Program Collection for the PC, 3rd ed., Springer-Verlag, Berlin, 2008; [4] A. V. Getling – Rayleigh-Bénard Convection. Structures and Dynamics, Worl Scientific, Singapore, 1998; [5] C. H. Skiadas, C. Skiadas – Handbook of Applications of Chaos Theory, CRC Press, Taylor & Francis Group, Boca Raton, FL, 2016; [6] R. Kılıç – A Practical Guide for Studying Chua's Circuits, World Scientific, Singapore, 2010; [7] B. J. West – Fractal Physiology and Chaos in Medicine, 2nd Edition, World Scientific, Singapore, 2013.
G	EDUCATION STYLE

LEARNING AND TEACHING METHODS	Experiment, synthesizing analysis, computer assisted education Presentation, demonstration, conversation, university lecture, synthesizing analysis
ASSESSMENT METHODS	Continuous, formative, summative
LANGUAGE OF INSTRUCTION	English