Academic course description

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| BACHELOR ‘S PROGRAMME3rd YEAR OF STUDY, 1st SEMESTER |

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| **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
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| 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
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| C | **Lecture content** |
|  | Main characteristics of complex systemsQualitative changes in the dynamics of complex systems. BifurcationsNegative 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. FractalsSelf-organization. Symmetry breaking. Spatial, temporal and spatio-temporal self-organized structures.Chaos. Routes to chaos. Quantities for chaotic states characterization. Chaos controlNetworks. Measures on networks. Functional networks. Dynamics on and of networksIntroduction 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.
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| E | **Seminar / laboratory content** |
|  | Analysis of negative differential resistance and hysteresis in plasmaPhysical models of complex systemsSelf-organized structures in plasma: fireball, multiple double layersRayleigh-Bénard convectionExperimental 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 noiseAnalysis of chaotic time series with specialized softwareChua chaotic circuit. Control of chaos. Synchronization of chaotic circuits. Chaos-based communicationControl of chaos in plasma by using external circuit elementsAnalysis 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 educationPresentation, demonstration, conversation, university lecture, synthesizing analysis |
| assessment methods | Continuous, formative, summative |
| Language of instruction | English |