UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Nelinearni dinamični sistemi
Course title:	Nonlinear Dynamical Systems

Študijski program in stopnja Study programme and level	**Študijska smer Study field**	**Letnik Academic year**	**Semester Semester**
Fizika 2. st.		1,2	2,3
Physics 2nd degree		1,2	2,3

Vrsta predmeta / Course type	izbirni/ optional
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	**Seminar Seminar**	**Sem. vaje Tutorial**	**Lab. vaje Laboratory work**	**Teren. vaje Field work**	**Samost. delo Individ. work**	**ECTS**
30	0	30	0	0	90	5

Nosilec predmeta / Lecturer:	Marko Marhl

Jeziki / Languages:	**Predavanja / Lectures:**	slovenski/Slovenian in/and angleški/English
	Vaje / Tutorial:	slovenski/Slovenian in/and angleški/English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Predznanje modelske fizike in fizike kompleksnih sistemov	Preknowledge of physics of complex systems and physics modelling

Vsebina:	**Content (Syllabus outline):**
1. **Nelinearni dinamični sistemi v 1D, 2D in 3D** Linearizacija in linearna stabilnostna analiza, bifurkacijska analiza. 2. **Nelinearni oscilatorji** Regularni oscilatorji kot konzervativni in disipativni sistemi (center, limitni cikel), bifurkacije, bifurkacijski diagram, lokalne in globalne bifurkacije. 3. **Kvaziperiodičnost, kaos** Fourierjeva transformacija in avtokorelacija, Lyapunovi eksponenti, kaos 4. **Fraktali in fraktalne dimenzije.** 5. **Stohastično modeliranje** (Gillespiev algoritem) 6. **Aplikacije** Pomen dinamičnih sistemov v fiziki in na drugih področjih: dinamični sistemi v biologiji, okoljevarstvu, ekonomiji, …. 7. **Uporaba računalniških programov** Uporaba računalniških programov za implementacijo dinamičnih sistemov: DynaSys, Stella, Madonna, C++, ...	1. **Nonlinear dynamical systems (1D-, 2D-, 3D-systems)** Linearization and the linear stability analysis, the bifurcation analysis. 2. **Nonlinear oscillators** Regular oscillators as conservative and dissipative systems (centre, limit cycle), bifurcations, bifurcation diagram, local and global bifurcations. 3. **Quasiperiodicity, chaos** Fourier transformation and autocorrelation, Lyapunov exponents. 4. **Fractals and fractal dimension** 5. **Stochastical modelling** (Gillespie's algorithm) 6. **Applications** The role of dynamical systems in physics and in other fields: dynamical systems in biology, environmental science, economy, … 7. **Using of computer programs** Computer programmes for the implementation of dynamical systems: DynaSys, Stella, Madonna, C++, ...

Temeljni literatura in viri / Readings:

1. Steven H. Strogatz, Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry, and Engineering. Perseus Pub., Cambridge, 1994.
2. J. B. Snape, I. J. Dunn, J. Ingham, J. E. Prenosil, Dynamics of Environmental Bioprocesses, Modelling and Simulation, VCH Verlagsgesellschaft, Weinheim, 1995.
3. Natali Hritonenko, Yuri Yatsenko, Mathematical Modeling in Economics, Ecology and the Environment, Springer, New York, 1999.
4. Strokovni in znanstveni članki v revijah / Articles published in professional and scientific journals.

Cilji in kompetence:

- Razvijati sposobnosti za opravljanje kvantitativne analize dinamike kompleksnih sistemov.
- Predstaviti ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah.
- Poudariti uporabnost znanja o dinamičnih sistemih v naravnih sistemih in prenos znanja na druga področja.
- Uporaba računalniških programov za implementacijo dinamičnih sistemov.

Objectives and competences:

- Developing skills for quantitative analysis of the dynamics of complex systems.
- Presenting basic differences and characteristics of dynamical systems in different dimensions.
- Pointing out the applicability of knowledge about dynamical systems in the nature and the transfer of knowledge to other fields.
- Using computer programs for the implementation of dynamical systems.

Predvideni študijski rezultati:

Znanje in razumevanje:

- Usvojiti metode za kvantitativno analizo dinamike kompleksnih sistemov.
- Spoznati ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah.
- Pomen determinističnega in stohastičnega modeliranja.
- Spoznati uporabnost znanja o dinamičnih sistemih v fiziki in prenos znanja na druga področja.
- Znati uporabljati računalniške programe za implementacijo dinamičnih sistemov.

Prenesljive/ključne spretnosti in drugi atributi:

- Metode kvantitativne analize dinamičnih sistemov so univerzalne in jih je mogoče uporabiti na najrazličnejših področjih.
- Poudarek je na prenosu znanja s primerov iz fizike na področja biologije, ekologije, ekonomije, …

Intended learning outcomes:

Knowledge and Understanding:

- Be able to use methods for quantitative analysis of the dynamics of complex systems.
- Know basic differences and characteristics of dynamical systems in different dimensions.
- Importance of deterministic and stochastic modelling.
- Be able to apply the knowledge about dynamical systems in physics to other fields.
- Using computer programs for the implementation of dynamical systems.

Transferable/Key Skills and other attributes:

- Methods for quantitative analysis of dynamical system are universal and can be implemented in different fields of research.
- In particular, a knowledge transfer from examples in physics to examples in biology, ecology, economics, etc. is emphasised.

Metode poučevanja in učenja:

- Predavanja
- Teoretične vaje
- Vaje na računalniku
- Eksperimentalne vaje

Learning and teaching methods:

- Lectures
- Theoretical exercises
- Computer exercises
- Experiments

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
• ustno • pisno • praktično - seminar	40 40 20	• oral • written • practical - seminar

Reference nosilca / Lecturer's references:

BODENSTEIN, Christian, KNOKE, Beate, MARHL, Marko, PERC, Matjaž, SCHUSTER, Stefan. Using Jensen's inequality to explain the role of regular calcium oscillations in protein activation. *Physical biology*, 2010, vol. 7, no. 3, str. 036009-1-036009-12, doi: 10.1088/1478-3975/7/3/036009. [COBISS.SI-ID 14376470]

GOSAK, Marko, KOROŠAK, Dean, MARHL, Marko. Optimal network configuration for maximal coherence resonance in excitable systems. *Phys. rev., E Stat. nonlinear soft matter phys. (Print)*, 2010, vol. 81, iss. 5, str. 056104-1-056104-7, ilustr., doi: 10.1103/PhysRevE.81.056104. [COBISS.SI-ID 17626120]

KNOKE, Beate, BODENSTEIN, Christian, MARHL, Marko, PERC, Matjaž, SCHUSTER, Stefan. Jensen's inequality as a tool for explaining the effect of oscillations on the average cytosolic calcium concentration.*Theory biosci.*, Jun. 2010, vol. 129, no. 1, str. 25-38, doi: 10.1007/s12064-010-0080-1. [COBISS.SI-ID 14376726]

GOSAK, Marko, KOROŠAK, Dean, MARHL, Marko. Topologically determined optimal stochastic resonance responses of spatially embedded networks. *New journal of physics*. [Online ed.], Jan. 2011, vol. 13, issue 1, str. 013012-1-013012-15, ilustr. http://dx.doi.org/10.1088/1367-2630/13/1/013012. [COBISS.SI-ID 18087432]

GOSAK, Marko, MARKOVIČ, Rene, MARHL, Marko. The role of neural architecture and the speed of signal propagation in the process of synchronization of bursting neurons. *Physica, A*. [Print ed.], 2012, vol. 391, no. 8, str. 2764-2770, ilustr., doi: 10.1016/j.physa.2011.12.027. [COBISS.SI-ID 18948872]