Univerza v Mariboru

Fakulteta za naravoslovje
in matematiko

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. Physics 2nd degree		1	2

Vrsta predmeta / Course type: izbirni / elective

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
15		30			105	5

Nosilec predmeta / Lecturer: Vladimir Grubelnik

Jeziki / Languages:		
	Predavanja / Lectures:	slovenski/Slovenian
	Vaje / Tutorial:	slovenski/Slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
Pogojev ni	None

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, fraktali in fraktalne dienzije. **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, chaos, fractals and fractal dimensions. **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:	**Objectives and competences:**

• Študentje bodo znali kvantitativno analizirati dinamiko kompleksnih sistemov. • Študentje bodo razumeli ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah. • Uporabiti znanje o dinamičnih sistemih v naravnih sistemih in drugih področjih. • Uporaba računalniških programov za implementacijo dinamičnih sistemov.	• Students will be able to quantitative analyse the dynamics of complex systems. • Students will be able to understand basic differences and characteristics of dynamical systems in different dimensions. • Using knowledge about dynamical systems in the nature and the other fields. • Using computer programs for the implementation of dynamical systems.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: • Uporabiti pridobljeno znanje pri kvantitativni analizi dinamike kompleksnih sistemov. • Razložiti ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah. • Razumeti deterministično in stohastično modeliranje. • Uporabiti znanje 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, …	Knowledge and Understanding: • apply this knowledge at quantitative analysis of the dynamics of complex systems. • explain the basic differences and characteristics of dynamical systems in different dimensions. • Understand the deterministic and stochastic modelling. • 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:	**Learning and teaching methods:**
• Predavanja • Teoretične vaje • Vaje na računalniku • Eksperimentalno delo	• Lectures • Theoretical exercises • Computer exercises • Experimental work

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
• izpit iz teoretičnih znanj	50	• exam of theoretical knowledge
• projektna naloga	50	• project work

Reference nosilca / Lecturer's references:

- MARKOVIČ, Rene, GOSAK, Marko, GRUBELNIK, Vladimir, MARHL, Marko, VIRTIČ, Peter. Data-driven classification of residential energy consumption patterns by means of functional connectivity networks. *Applied energy*, ISSN 0306-2619, 2019, vol. 242, str. 506-515, graf. prikazi, doi: 10.1016/j.apenergy.2019.03.134. [COBISS.SI-ID1024346460]
- MARKOVIČ, Rene, GOSAK, Marko, PERC, Matjaž, MARHL, Marko, GRUBELNIK, Vladimir. Applying network theory to fables : complexity in Slovene belles-lettres for different age groups. *Journal of complex networks*, ISSN 2051-1329. [Online ed.], 2019, vol. 7, issue 1, str. 114-127, doi: 10.1093/comnet/cny018. [COBISS.SI-ID 24086536]
- GRUBELNIK, Vladimir, LOGAR, Marjan, ROBNIK, Marko, XIA, Yong-Hui. Analysis of the parametrically periodically driven classical and quantum linear oscillator. *Physical review. E.*, ISSN 2470-0053, Feb. 2019, vol. 99, issue 2, str. 022209-1 - 022209-14, graf. prikazi, tabele, doi: 10.1103/PhysRevE.99.022209. [COBISS.SI-ID96173569]
- GRUBELNIK, Vladimir, LOGAR, Marjan, ROBNIK, Marko. Quantum Fermi acceleration in the resonant gaps of a periodically driven one-dimensional potential box. Journal of physics. A, Mathematical and theoretical, ISSN 1751-8113, 2014, vol. 47, no. 35, str. 355103-1 - 355103-17, doi: 10.1088/1751-8113/47/35/355103. [COBISS.SI-ID 18017814]
- FORJAN, Matej, MARHL, Marko, GRUBELNIK, Vladimir. Mathematical modelling of the electrostatic pendulum in school and undergraduate education. European journal of physics, ISSN 0143-0807, 2014, vol. 35, no. 1, str. 015022-1-015022-13, doi: 10.1088/0143-0807/35/1/015022. [COBISS.SI-ID 20357128]

BODENSTEIN, Christian, GOSAK, Marko, SCHUSTER, Stefan, MARHL, Marko, PERC, Matjaž. Modeling the seasonal adaptation of circadian clocks by changes in the network structure of the suprachiasmatic nucleus. PLOS comput. biol., Sep. 2012, vol. 8, iss. 9, e1002697-1-e1002697-12.

MARHL, Marko, GOSAK, Marko, PERC, Matjaž, ROUX, Etienne. Importance of cell variability for calcium signaling in rat airway myocytes. Biophysical chemistry. [Print ed.], 2010, vol. 148, iss. 1/3, str. 42-50.

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.

GRUBELNIK, Vladimir, DUGONIK, Bogdan, OSEBIK, Davorin, MARHL, Marko. Signal amplification in biological and electrical engineering systems : universal role of cascades. Biophysical chemistry. [Print ed.], aug. 2009, vol. 143, iss. 3, str. 132-138.

MARHL, Marko, GOSAK, Marko, PERC, Matjaž, DIXON, C. Jane, GREEN, Anne K. Spatio-temporal modelling explains the effect of reduced plasma membrane Ca[sup]2+ efflux on intracellular Ca[sup]2+ oscillations in hepatocytes. J. theor. biol., 2008, vol. 252, iss. 3, str. 419-426.