Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Dinamični sistemi
Course title:	Dynamical Systems

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Fizika, 1. stopnja		**3**	**5**
Physics, 1st cycle		**3**	**5**

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

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Lab. work	Druge oblike študija	Samost. delo Individ. work	ECTS
45			**30**		**105**	**6**

Nosilec predmeta / Lecturer:	Matjaž Perc

Jeziki / Languages:	**Predavanja / Lectures:**	slovensko / Slovenian
	Vaje / Tutorial:	slovensko / Slovenian

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

Vsebina:	**Content (Syllabus outline):**
1. Preprosti matematični opis dinamike sistema (enodimenzionalni (1D) sistemi) Splošna definicija dinamičnih sistemov, avtonomnost dinamičnega sistema, fazni prostor, linearna stabilnostna analiza, bifurkacijska analiza, enodimenzionalni sistemi in oscilacije. 2. Dinamični sistemi in oscilacije (2D sistemi) Linearni 2D sistemi, nelinearni 2D sistemi, linearizacija sistema in linearna stabilnostna	1. Basic mathematical description of the system dynamics (one-dimensional (1D) systems) Definition of dynamical systems, autonomous dynamical systems, the phase space, the linear stability analysis, the bifurcation analysis, one-dimensional systems and oscillations. 2. Dynamical systems and oscillations (2D systems) Linear 2D systems, nonlinear 2D systems, linearization and linear stability analysis,

analiza, konzervativni in disipativni sistemi, oscilator – konzervativni sistemi, oscilator – disipativni sistem, bifurkacije, bifurkacijski diagram, lokalne in globalne bifurkacije. 3. Kompleksni atraktorji (3D sistemi) Fourierjeva transformacija in avtokorelacija, Lyapunovi eksponenti, regularni atraktorji v 3D, kaos, čudni atraktorji in fraktalne dimenzije. 4. Aplikacije Pomen dinamičnih sistemov v fiziki in na drugih področjih: dinamični sistemi v biologiji, okoljevarstvu, ekonomiji, …. 5. Uporaba računalniških programov Uporaba računalniških programov za implementacijo dinamičnih sistemov: DynaSys, Stella, Madonna, C++, ...	conservative and dissipative systems, oscillator – conservative system, oscillator – dissipative system, bifurcations, bifurcation diagram, local and global bifurcations. 3. Complex attractors (3D systems) Fourier transformation and autocorrelation, Lyapunov exponents, regular attractors in 3D, chaos, strange attractors and fractal dimensions. 4. Applications The role of dynamical systems in physics and in other fields: dynamical systems in biology, environmental science, economy, … 5. Using of computer programs Computer programmes for the implementation of dynamical systems: DynaSys, Stella, Madonna, C++, ...

Temeljni literatura in viri / Readings:

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

Pripombe dodal [NV1]: Če je možno, prosim, da dodaš (vsaj) en slovenski vir.

Cilji in kompetence:	**Objectives and competences:**
Razviti sposobnosti za opravljanje kvantitativne analize dinamike kompleksnih sistemov. Razumeti ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah. Poznati uporabnost znanja o dinamičnih sistemih v naravnih sistemih in prenos znanja na druga področja. Znati uporabiti računalniške programe za implementacijo dinamičnih sistemov.	Develop the skills for quantitative analysis of the dynamics of complex systems. Understand the basic differences and characteristics of dynamical systems in different dimensions. Know the applicability of knowledge about dynamical systems in the nature and the transfer of knowledge to other fields. Use computer programs for the implementation of dynamical systems.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Usvojiti metode za kvantitativno analizo dinamike kompleksnih sistemov. Spoznati ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah. 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, …	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. 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:	**Learning and teaching methods:**
Predavanja Vaje na računalniku	Lectures Computer exercises

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt): ustni izpit opravljene vaje na računalniku Za uspešno zaključeno učno enoto mora biti vsak del posebej pozitiven. Opravljene vaje na računalniku so pogoj za pristop k izpitu.	 50 50	Type (examination, oral, coursework, project): oral exam done computer exercises For a successfully finished course, both parts have to be positive. Done computer exercises are a prerequisite to access the oral exam.

Reference nosilca / Lecturer's references:

1. BAYANI, Atiyeh, JAFARI, Sajad, AZARNOUSH, Hamed, NAZARIMEHR, Fahimeh, BOCCALETTI, Stefano, PERC, Matjaž. Explosive synchronization dependence on initial conditions : the minimal Kuramoto model. *Chaos, solitons and fractals*. [Print ed.]. Apr. 2023, vol. 169, [article no.] 113243, 6 str. DOI: 10.1016/j.chaos.2023.113243. [COBISS.SI-ID 144690435]

2. BARAĆ, Uroš, PERC, Matjaž, GOSAK, Marko. Determinants of collective failure in excitable networks. *Chaos*. 2023, vol. 33, iss. 4, [article no.] 043120, 9 str. ISSN 1054-1500. DOI: 10.1063/5.0149578. [COBISS.SI-ID 149413891]
3. KHATAMI, Saideh, BOLHASANI, Ehsan, PERC, Matjaž, VALIZADEH, Alireza. Flexible patterns of information transfer in frustrated networks of phase oscillators. *Nonlinear dynamics*. Feb. 2023, vol. 111, iss. 3, str. 2681-2691. ISSN 0924-090X. DOI: 10.1007/s11071-022-07936-z. [COBISS.SI-ID 137497859]
4. HU, Kaipeng, LI, Zhouhong, SHI, Lei, PERC, Matjaž. Evolutionary games with two species and delayed reciprocity. *Nonlinear dynamics*. Apr. 2023, vol. 111, iss. 8, str. 7899-7910. ISSN 0924-090X. DOI: 10.1007/s11071-023-08231-1. [COBISS.SI-ID 145456387]
5. GAO, Shupeng, CHANG, Lili, PERC, Matjaž, WANG, Zhen. Turing patterns in simplicial complexes. *Physical review. E*. Jan. 2023, vol. 107, iss. 1, [article no.] 014216, 14 str. ISSN 2470-0045. DOI: 10.1103/PhysRevE.107.014216. [COBISS.SI-ID 139890691]