Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Dinamični sistemi v fiziki in biologiji
Course title:	Dynamical Systems in Physics and Biology

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
FIZIKA		1. ali 2.	**1., 2. ali 4.**
PHYSICS		1. or 2.	**1., 2. or 4.**

Vrsta predmeta / Course type	Izbirni vse module
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Lab. Vaje Laboratory work	Terenske vaje Field work	Samost. Delo Individ. Work	ECTS
10	5				165	6

Nosilec predmeta / Lecturer:	Marko Marhl

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
Ni posebnih zahtev.	No special prerequisites.

Vsebina:	Content (Syllabus outline):
1. Kvantitativni opis dinamike kompleksnih fizikalnih in bioloških sistemov Matematičen opis dinamike sistemov; zapis diferencialnih enačb. **2. Stabilnostna in bifurkacijska analiza** Linearizacija in linearna stabilnostna analiza, bifurkacijska analiza.	**1. Quantitative description of the dynamics of complex system in physics and biology** Mathematical description of the systems dynamics; differential equations. **2. Stability and bifurcation analysis** Linearization and linear stability analysis, bifurcation analysis.

3. Oscilatorni sistemi
Regularni oscilatorji v fiziki in biologiji
Kvaziperiodičnost, kaotični atraktorji
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 biologiji ter prikaz uporabe metod tudi na drugih področjih: v okoljevarstvu, ekonomiji, ...

7. Uporaba racunalniških programov
Uporaba računalniških programov za implementacijo dinamičnih sistemov: DynaSys, Stella, Madonna, C++, ...

3. Oscillatory systems
Regular oscillators in physics and biology
Quasiperiodicity, chaotic attractors
Fourier transformation and autocorrelation, Lyapunov exponents, chaos.

4. Fractals and fractal dimension

5. Stochastical modelling
Gillespie’s algorithm

6. Applications
The role of dynamical systems in physics and biology, and application of the methods in other fields: in 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 fizikalnih in bioloških sistemov.

• Predstaviti ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah.

• Poudariti uporabnost znanja o dinamičnih sistemih v fizikalnih in bioloških sistemih ter prenos znanja na druga področja.

Objectives and competences:

• Developing skills for quantitative analysis of dynamics of complex systems in physics and biology.

• Presenting basic differences and characteristics of dynamical systems in different dimensions.

• Pointing out the applicability of knowledge about dynamical systems in physics and biology, and transfer of knowledge to other fields.

• Uporaba računalniških programov za implementacijo dinamičnih sistemov.	• Using computer programs for the implementation of dynamical systems.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: • Usvojiti metode za kvantitativno analizo dinamike kompleksnih fizikalnih in bioloških 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 biologiji ter 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 in biologije na področja ekologije, ekonomije, …	Knowledge and understanding: • Be able to use methods for quantitative analysis of the dynamics of complex systems in physics and biology. • 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 and biology, and transfer of knowledge 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 and biology to ecology, economics, etc. is emphasised.

Metode poučevanja in učenja:	**Learning and teaching methods:**
• Predavanja • Teoretične vaje • Vaje na računalniku • Eksperimentalne vaje	• Lectures • Theoretical exercises • Computer exercises • Experiments

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt)	**40%** **40%** **20%**	Type (examination, oral, coursework, project):

• ustn izpit • pisni izpit • praktično – seminarska naloga		• oral exam • written exam • practical - seminar

Reference nosilca / Lecturer's references:

1. GOSAK, Marko, STOŽER, Andraž, MARKOVIČ, Rene, DOLENŠEK, Jurij, MARHL, Marko, RUPNIK, Marjan, PERC, Matjaž. The relationship between node degree and dissipation rate in networks of diffusively coupled oscillators and its significance for pancreatic beta cells. *Chaos*, ISSN 1054-1500, July 2015, vol. 25, iss. 7, 073115-1-073115-8, doi: 10.1063/1.4926673. [COBISS.SI-ID 512523576]

2. GOSAK, Marko, DOLENŠEK, Jurij, MARKOVIČ, Rene, RUPNIK, Marjan, MARHL, Marko, STOŽER, Andraž. Multilayer network representation of membrane potential and cytosolic calcium concentration dynamics in beta cells. *Chaos, solitons and fractals*. [Print ed.], 2015, vol. 80, str. 76-82, ilustr. http://www.sciencedirect.com/science/article/pii/S0960077915001794, doi: 10.1016/j.chaos.2015.06.009. [COBISS.SI-ID 512513080]

3. MARKOVIČ, Rene, STOŽER, Andraž, GOSAK, Marko, DOLENŠEK, Jurij, MARHL, Marko, RUPNIK, Marjan. Progressive glucose stimulation of islet beta cells reveals a transition from segregated to integrated modular functional connectivity patterns. *Scientific reports*, ISSN 2045-2322, vol. 5, 2015, 10 str. http://www.nature.com/srep/2015/150119/srep07845/full/srep07845.html, doi: 10.1038/srep07845. [COBISS.SI-ID 512466488]

4. MARKOVIČ, Rene, GOSAK, Marko, MARHL, Marko. Broad-scale small-world network topology induces optimal synchronization of flexible oscillators. *Chaos, solitons and fractals*. [Print ed.], 2014, vol. 69, str. 14-21. http://dx.doi.org/10.1016/j.chaos.2014.08.008. [COBISS.SI-ID 20845576]

5. 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, Statistical mechanics and its applications*, ISSN 0378-4371. [Print ed.], 2012, vol. 391, no. 8, str. 2764-2770, ilustr., doi: 10.1016/j.physa.2011.12.027. [COBISS.SI-ID 18948872]