



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 KOMPLEKSNIH SISTEMOV		1. ali 2.	1., 2. ali 3.
PHYSICS OF COMPLEX SYSTEMS		1. or 2.	1., 2. or 3.

Vrsta predmeta / Course type

Izbirni za modula Biofizika 3 in Fizika 1, 2 in 3

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
7	8				435	15

Nosilec predmeta / Lecturer:

Marko Marhl

Jeziki /

Languages:

Predavanja /

Lectures:

slovenski/Slovenian

Vaje / Tutorial:

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Ni posebnih zahtev.

Prerequisites:

No special prerequisites.

Vsebina:

1. Kvantitativni opis dinamike kompleksnih fizikalnih in bioloških sistemov

Matematičen opis dinamike sistemov; zapis

Content (Syllabus outline):

1. Quantitative description of the dynamics of complex system in physics and biology

Mathematical description of the systems

diferencialnih enačb.

2. Stabilnostna in bifurkacijska analiza

Linearizacija in linearna stabilnostna analiza, bifurkacijska analiza.

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 računalniških programov

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

dynamics; differential equations.

2. Stability and bifurcation analysis

Linearization and linear stability analysis,
bifurcation analysis.

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. Stochastic 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.

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.

- Poudariti uporabnost znanja o dinamičnih sistemih v fizikalnih in bioloških sistemih ter prenos znanja na druga področja.
- Uporaba računalniških programov za implementacijo dinamičnih sistemov.

Predvideni študijski rezultati:

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, ...

- Pointing out the applicability of knowledge about dynamical systems in physics and biology, and transfer of knowledge to other fields.
- Using computer programs for the implementation of dynamical systems.

Intended learning outcomes:

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:

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

Learning and teaching methods:

- Lectures
- Theoretical exercises
- Computer exercises
- Experiments

Načini ocenjevanja:

Način (pisni izpit, ustno izpraševanje, naloge, projekt)

- ustn izpit

Delež (v %) /

Weight (in %)

Assessment:

Type (examination, oral, coursework, project):

- oral exam

40%

40%

20%

<ul style="list-style-type: none"> • pisni izpit • praktično – seminarska naloga 		<ul style="list-style-type: none"> • written exam • practical - seminar
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Reference nosilca / Lecturer's references:

1. 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](https://doi.org/10.1088/0143-0807/35/1/015022). [COBISS.SI-ID [20357128](#)]
2. GOSAK, Marko, GUIBERT, Christelle, BILLAUD, Marie, ROUX, Etienne, MARHL, Marko. The influence of gap junction network complexity on pulmonary artery smooth muscle reactivity in normoxic and chronically hypoxic conditions. *Experimental physiology*, ISSN 0958-0670, 2014, vol. 99, no. 1, str. 272-285, doi: [10.1113/expphysiol.2013.074971](https://doi.org/10.1113/expphysiol.2013.074971). [COBISS.SI-ID [20068872](#)]
3. 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*, ISSN 0378-4371. [Print ed.], 2012, vol. 391, no. 8, str. 2764-2770, ilustr., doi: [10.1016/j.physa.2011.12.027](https://doi.org/10.1016/j.physa.2011.12.027). [COBISS.SI-ID [18948872](#)]
4. MARHL, Marko, GOSAK, Marko, PERC, Matjaž, ROUX, Etienne. Importance of cell variability for calcium signaling in rat airway myocytes. *Biophysical chemistry*, ISSN 0301-4622. [Print ed.], 2010, vol. 148, iss. 1/3, str. 42-50, doi: [10.1016/j.bpc.2010.02.006](https://doi.org/10.1016/j.bpc.2010.02.006). [COBISS.SI-ID [14070550](#)]
5. GOSAK, Marko, KOROŠAK, Dean, MARHL, Marko. Optimal network configuration for maximal coherence resonance in excitable systems. *Physical review. E, Statistical, nonlinear, and soft matter physics*, ISSN 1539-3755, 2010, vol. 81, iss. 5, str. 056104-1-056104-7, ilustr., doi: [10.1103/PhysRevE.81.056104](https://doi.org/10.1103/PhysRevE.81.056104). [COBISS.SI-ID [17626120](#)]