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, 3. stopnja		**1. ali 2.**	**1., 2. ali 4.**
PHYSICS, 3rd cycle		**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 računalniških 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:	**Objectives and competences:**
Cilj tega predmeta je, da se študenti usposobijo uporabiti kvantitativni opis dinamike sistemov pri svojem raziskovalnem delu. Operativni cilji so: • razviti sposobnosti za opravljanje kvantitativne analize dinamike kompleksnih fizikalnih in bioloških sistemov;	The objective of this course is for students to be able to apply the quantitative description of systems dynamics in their research work. The operative objectives are: • developing skills for quantitative analysis of dynamics of complex systems in physics and biology;

• analizirati 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; • uporaba računalniških programov za implementacijo dinamičnih sistemov.	• analysing 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. • using computer programs for the implementation of dynamical systems.
Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Po zaključku tega predmeta bo študent sposoben: • razumeti in uporabiti metode za kvantitativno analizo dinamike kompleksnih fizikalnih in bioloških sistemov; • razlikovati in matematično ovrednotiti karakteristike dinamičnih sistemov v različnih dimenzijah; • aplicirati metode deterministčnega in stohastičnega modeliranja na dejanske primere fizikalnih in bioloških sistemov; • evalvirati in sintetizirati znanja o dinamičnih sistemih v fiziki in biologiji ter jih prenesti tudi na druga področja; • uporabljati računalniške programe za implementacijo dinamičnih sistemov. **Prenesljive/ključne spretnosti in drugi atributi:** • *Spretnosti komuniciranja:* ustni zagovor vaj, pisno izražanje pri pisnem izpitu. • *Uporaba informacijske tehnologije:* uporaba računalniških programov za modeliranje sistemov. • *Reševanje problemov:* reševanje problemov z uporabo matematičnega modeliranja dinamike sistemov. • *Prenos znanja na druga področja:* prenos znanja s primerov iz fizike na področja populacijske dinamike, okoljskih problemov, bioloških sistemov, …	**Knowledge and understanding:** On completion of this course the student will be able to: • understand and implement methods for quantitative analysis of the dynamics of complex systems in physics and biology; • differentiate and mathematically evaluate the characteristics of dynamical systems in different dimensions; • implement methods of deterministic and stochastic modelling on real systems in physics and biology; • evaluate and synthesize knowledge on dynamical systems in physics and biology, and transfer this knowledge to other fields; • use computer programs for the implementation of dynamical systems. **Transferable/Key Skills and other attributes:** • *Communication skills:* oral defense of practical work, manner of expression at written examination. • *Use of information technology:* use of computer programs for systems modelling. • *Problem solving:* problem solving with implementing mathematical modelling of systems dynamics. • *Transfer of knowledge to other fields:* knowledge transfer from examples in physics to examples in population dynamics, environment and biological systems, …

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)		Type (examination, oral, coursework, project):
• ustn izpit	**40%**	• oral exam
• pisni izpit	**40%**	• written exam
• praktično – seminarska naloga	**20%**	• practical - seminar

Reference nosilca / Lecturer's references:

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. [COBISS.SI-ID 20068872], [JCR, SNIP, WoS]

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], [JCR, SNIP, WoS]

MARKOVIČ, Rene, GOSAK, Marko, REPNIK, Robert, KRALJ, Samo, **MARHL, Marko**. Defects in planar cell polarity of epithelium : what can we learn from liquid crystals?. V: IGLIČ, Aleš (ur.), KULKARNI, Chandrashekhar (ur.). *Advances in planar lipid bilayers and liposomes*, (Advances in planar lipid bilayers and liposomes, ISSN 1554-4516, vol. 20). Amsterdam [etc.]: Elsevier: Academic Press. cop. 2014, str. 197-217, ilustr., doi: 10.1016/B978-0-12-418698-9.00008-3. [COBISS.SI-ID 20825864], [WoS, Scopus]

GOSAK, Marko, STOŽER, Andraž, MARKOVIČ, Rene, DOLENŠEK, Jurij, PERC, Matjaž, RUPNIK, Marjan, **MARHL, Marko**. Critical and supercritical spatiotemporal calcium dynamics in beta cells. *Frontiers in physiology*, ISSN 1664-042X, 2017, vol. 8, str. 1-17, ilustr., doi: 10.3389/fphys.2017.01106. [COBISS.SI-ID 512760376], [JCR, SNIP, WoS]

GOSAK, Marko, MARKOVIČ, Rene, DOLENŠEK, Jurij, RUPNIK, Marjan, **MARHL, Marko**, STOŽER, Andraž, PERC, Matjaž. Network science of biological systems at different scales : a review. *Physics of life reviews*, ISSN 1873-1457, 2018, vol. 24, str. 118-135, doi: 10.1016/j.plrev.2017.11.003. [COBISS.SI-ID 512746040], [JCR, SNIP, WoS]