UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	**Modeliranje sistemske dinamike**
Course title:	**System Dynamics Modelling**

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Enovit magistrski študijski program druge stopnje Predmetni učitelj	**Izobraževalna fizika**	**3**	**6**
Five-year master's degree program Subject Teacher	**Educational physics**		

Vrsta predmeta / Course type izbirni

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
45			**30**		**135**	**7**

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:**
Pogojev ni.	None.

Vsebina:	**Content (Syllabus outline):**
1. Kvalitativna analiza kompleksnih sistemov. 2. Kvantitativna analiza dinamike kompleksnih sistemov: določanje spremenljivk v sistemu, ki opisujejo stanja in tokove. Medsebojni vplivi in zunanji vplivi na posamezne spremenljivke. 3. Kvantitativni opis modela sistemske dinamike; prehod s kavzalnih diagramov in diagramov stanj in tokov na matematičen opis vpliva tokov količin na njihovo dinamiko; diferenčne enačbe 4. Konstruiranje matematičnih modelov v fiziki; prikaz prednosti modelnega pristopa; primeri, ki so analitično težko rešljivi: npr. upoštevanje zračnega upora v primerih iz kinematike, …;	1. Qualitative analysis of complex systems. 2. Quantitative analysis of the dynamics of complex systems: determination of system variables – the socalled stock and flow variables. Interrelated influences and external influences on the variables. 3. Quantitative modelling of system dynamics; quantification of causal-loop diagrams and stock-flow diagrams; mathematical description of influences of fluxes on system variables; model equations. 4. Construction of mathematical models in Physics; pointing out the advantages of the modelling approach; examples of analytically

primeri, ki nakazujejo univerzalnost pristopov: npr. modeliranje radioaktivnih razpadov, …. 5. Aplikacije v fiziki in na drugih področjih: modeli populacijske dinamike, biološki sistemi, … 6. Uporaba računalniških programov za modeliranje sistemske dinamike: grafično orientirani programi DynaSys, Stella, Madonna, …; primerjava z Excel, C++.	difficult-solvable problems: kinematics with air resistance, …; examples of generalisation of approaches: e.g. modelling of radioactive decay, … 5. Applications in Physics and other fields: modelling of population dynamics, biological systems, … 6. Using computer programs for modelling of system dynamics: graphic-oriented computer programmes: DynaSys, Stella, Madonna, …; comparison with Excel, C++.

Temeljni literatura in viri / Readings:

- S. H. Strogatz, Nonlinear Dynamics and Chaos. With Applications to Phzsics, Biology, Chemistry, and Engineering, Perseus Books Publishing, New York (1994).
- H. P. Schecker, Physik-Modellieren, Grafikorientierte Modellbildungssysteme im Physikunterricht, Ernst Klett Verlag, Stuttgart (1998).
- J. B. Snape, I. J. Dunn, J. Ingham, J. E. Prenosil, Dynamics of Environmental Bioprocesses, Modelling and Simulation, VCH Verlagsgesellschaft, Weinheim 1995.
- Strokovni in znanstveni članki v revijah / Articles published in professional and scientific journal

Cilji in kompetence:	**Objectives and competences:**
Cilj tega predmeta je, da bodo študenti razumeli, kako kvalitativno in kvantitativno opišemo dinamiko sistemov. Operativni cilji so: • predstaviti metode kvalitativne analize kompleksnih sistemov, • razviti sposobnosti za kvantitativni opis kompleksnih sistemov, • naučiti študente osnov matematičnega modeliranja, • poudariti univerzalnost metod in prenos znanja na druga področja, • naučiti študente uporabljati računalniške programe za modeliranje sistemov (npr. Madonna, ...).	The objective of this course is for students to be able to qualitative and quantitative describe systems dynamics. The operative objectives are: • presenting methods for qualitative complex systems analysis, • developing skills for quantitative analysis of complex systems, • giving basics of mathematical modelling, • emphasizing universality of the methods and knowledge transfer to other fields, • developing skills for using computer programs for system dynamics modelling (e.g. Madonna, …).

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Po zaključku tega predmeta bo študent sposoben: • razumeti in uporabiti metode za kvalitativno analizo kompleksnih sistemov, • razumeti osnove matematičnega	**Knowledge and understanding:** On completion of this course the student will be able to: • understand and implement methods for qualitative analysis of complex systems, • understand basics of mathematical modelling,

modeliranja, • uporabiti metode za kvantitativno analizo kompleksnih sistemov, • uporabljati računalniške programe za modeliranje sistemske dinamike. **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, …	• implement methods for quantitative analysis of complex systems, • use computer programs for modelling systems dynamics. **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 Experiment

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

Reference nosilca / Lecturer's references:

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 do 9. 6. 2019: št. citatov (TC): 42, čistih citatov (CI): 39, Scopus do 29. 5. 2019: št. citatov (TC): 57, čistih citatov (CI): 52]

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-ID 1024346460], [JCR, SNIP, Scopus do 29. 4. 2019: št. citatov (TC): 1, čistih citatov (CI): 1]

MARKOVIČ, Rene, PELTAN, Julien, GOSAK, Marko, HORVAT, Denis, ŽALIK, Borut, SEGUY, Benjamin, CHAUVEL, Remi, MALANDAIN, Gregoire, COUFFINHAL, Thierry, DUPLÁA, Cécile, MARHL, Marko, ROUX, Etienne. Planar cell polarity genes frizzled4 and frizzled6 exert patterning influence on arterial vessel morphogenesis. *PloS one*, ISSN 1932-6203, 2017, vol. 12, iss. 3, str. 1-19, doi: 10.1371/journal.pone.0171033. [COBISS.SI-ID 22990856], [JCR, SNIP, WoS do 12. 5. 2019: št. citatov (TC): 3, čistih citatov (CI): 2, Scopus do 29. 5. 2019: št. citatov (TC): 3, čistih citatov (CI): 2]

ROUX, Etienne, MARHL, Marko. Theoretical analysis of the vascular system and its relation to Adrian Bejan's constructal theory. *Journal of Theoretical and Applied Vascular Research*, ISSN 2532-0831, Feb. 2017, vol. 2, iss. 1, str. 1-6, doi: 10.24019/jtavr.20. [COBISS.SI-ID 24300552]

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 do 12. 5. 2019: št. citatov (TC): 5, čistih citatov (CI): 4, Scopus do 29. 5. 2019: št. citatov (TC): 6, čistih citatov (CI): 5]