Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

UČNI NAČRT PREDMETA / *COURSE SYLLABUS*	
Predmet:	Napredni mehatronski sistemi
Course title:	Advanced mechatronic systems

Študijski program *Study programme and level*	**Študijska smer** *Study field*	**Letnik** *Academic year*	**Semester** *Semester*
Inženiring in avtomobilska industrija Podiplomski (tretja)	Program nima smeri	prvi	prvi
Engineering and Automotive Industry Graduate – Master (third)	The program has no study fields	first	first

Vrsta predmeta / *Course type*	Izbirni	Optional
Univerzitetna koda predmeta / *University course code:*	31004 - 02	

Predavanja *Lectures*	**Seminar** *Seminar*	**Sem. vaje** *Tutorial*	**Lab. vaje** *Laboratory work*	**Teren. vaje** *Field work*	**Samost. delo** *Individ. work*	**ECTS**
60	-	30	-	-	180	10

Nosilec predmeta / *Lecturer:*	**Prof. dr. Rudolf Pušenjak**

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	***Prerequisits:***
Vpis v prvi letnik študija	Enrolment in the first year of study

Vsebina:	***Content (Syllabus outline):***
- Modeliranje mehatronskih sistemov. - Kinematika sistemov z več telesi. Nadomestni mehanski sistemi z drevesno strukturo. Denavit-Hartenbergova notacija. Direktna in inverzna kinematika, kinematika robotov. Diferencialna kinematika. - Kinetika sistemov z več telesi. Newton-Eulerjeva metoda. Lagrangeova metoda. - Kinematično načrtovanje trajektorij. Načrtovanje trajektorij z inverzno dinamiko. Parametrizacija gibalnih enačb pri manipulatorjih. - Regulacija mehatronskih sistemov. Linearizacija gibalnih enačb. Zasnova regulacije linearnih sistemov z več spremenljivkami. Optimalna linearna regulacija in regulacija z opazovalnikom stanja. Digitalna regulacija. Pregled naprednih	- Modeling of mechatronic systems. - Kinematics of multi-body systems. Substitute mechanical systems with tree-structure. Denavit-Hartenberg notation. Direct and inverse kinematics, kinematics of robots. Differential kinematics. - Kinetics of multi-body systems. Newton-Euler method. Lagrange's method. - The kinematic planning of trajectories. Planning of trajectories through inverse dynamics. Parametrization of equations of motion in the case of manipulators. - The control of mechatronic systems. Linearization of equations of motion. The design of the control of multivariable linear systems. The optimal linear control and the control with an observer. The digital control. The survey of advanced control procedures. - The selected examples of modeling of mechatronic systems.

postopkov regulacije. - Izbrani primeri modeliranja mehatronskih sistemov.	

Temeljni literatura in viri / *Readings:*

- Pušenjak, R., Oblak, M. (2015). *Mehatronika I, elektronsko učno gradivo*. Fakulteta za industrijski inženiring: Novo mesto.

Priporočljiva literatura / *Recomended Textbooks*

- Isermann, R. (2005). *Mechatronic Systems: Fundamentals*. Springer.
- Heimann, B., Gerth, W.K., & Popp, K. (2006). *Mechatronik*. Carl Hanser Verlag.
- Czichos, H. (2006). *Mechatronik: Grundlagen und Anwendungen technischer Systeme*. Vieweg Verlag.
- G. Schmitz, Mechatronik im Automobil, Expert Verlag, 2003
- Bishop, R. H. (2002). *The Mechatronics Handbook*. CRC Press.

Cilji in kompetence:	**Objectives and competences:**
Cilji - Predmet je namenjen pridobitvi poglobljenih znanj iz mehatronike, sinteze inregulacije mehatronskih sistemov, novih pristopov pri gradnji in možnostih uporabe s poudarkom na avtomobilski industriji. ***Kompetence*** *Učna enota prispeva k razvoju naslednjih splošnih in specifičnih kompetenc:* - sposobnost razčlenitve problemov,izvedbe njihove analize in sinteze, - sposobnost uporabe naprednih razvojnih metod, postopkov in procesov, - sposobnost uporabe pridobljenega teoretičnega znanja v praksi, - avtonomnost v strokovnem delu na področju tehnologij, merilne in pogonske tehnike, upravljanja procesov ter informacijskih sistemov, - sposobnost razumevanja in uporabe sodobnih teorij s področja tehniških, tehnoloških in naravoslovnih ved, - sposobnost uporabe matematičnih metod pri reševanju problemov mehatronike, - sposobnost uporabe sodobnih informacijskih in komunikacijskih tehnologij na področju mehatronike.	***Objectives*** - This subject is intended for acquirement of in-depth knowledge in mechatronics, synthesis and control of mechatronic systems as well as new approaches in the design and use of mechatronic systems with emphasis on the automotive industry. ***Competences*** *The subject contributes to the development of the following common and specific competences, respectively:* - ability to analyze problems of mechatronics and to perform their synthesis, - ability to use the advanced development methods, procedures and processes, - ability to apply acquired theoretical knowledge in practice, - professional autonomy in the field of technologies, measurement systems and drives, process control and information systems, - the ability to understand and use of modern theory of engineering , technology and natural sciences, - ability to use the mathematical methods in solving problems of mechatronics, - ability to use the modern information and communication technologies in the field of mechatronics.

Predvideni študijski rezultati:	***Intended learning outcomes:***
Znanje in razumevanje: - student/ka pozna in razume strukturo mehatronskih sistemov, - jih zna razvrščati v posamezne skupine in podskupine,	***Knowledge and understanding:*** - student understands the structure of mechatronics systems, - knows how to divide mechatronic system into individual groups and subgroups,

- pozna lastnosti komponent in njihovo namembnost, - obvlada metode sinteze mehatronskih sistemov - pozna omejitve v sintezi mehatronskih sistemov, - zna načrtovati, uporabljati standarde in literaturo.	- knows the properties of the components and their purpose, - has mastered the methods of synthesis of mechatronic systems - knows limitations in synthesis of mechatronics systems, - knows projecting as well as using standards and literature.

Metode poučevanja in učenja:	***Learning and teaching methods:***
- *predavanja* z aktivno udeležbo študentov, ki vsebujejo razprave, diskusije, odgovore na vprašanja in reševanje nalog ob pomoči sodobnih pedagoških pripomočkov, - *seminarska naloga* iz mehatronskih sistemov na posameznih področjih, ki joštudentje izdelajo v skladu z usmeritvami in pomočjo predavatelja	- *lectures* with active attendance of students, which incorporate discussions, answers on the questions and solving of exercises with application of the contemporary pedagogical aids - *seminar work* involving mechatronic system on selected area of practice, which is performed under supervision of the lecturer

Načini ocenjevanja:	**Delež (v %) / *Weight (in%)***	***Assessment:***
Način (pisni izpit, ustno izpraševanje, naloge, projekt) Pogoj za pristop k izpitu je pozitivno ocenjena seminarska naloga. - seminarska naloga - ustni/pisni izpit Končna ocena izpita je povprečje ocene seminarske naloge in ustnega/pisnega izpita.	 60% 40%	Type (examination, oral, coursework, project): The prerequisite for accession to the exam is positive grade of the seminar work - seminar work - oral/written exam The final grade of the exam is the weighted average of both grades of the seminar work and the oral/written exam.

Reference nosilca / *Lecturer's references:*

- PUŠENJAK, Rudi. Nonlinear almost periodic analysis of FET amplifiers by incremental harmonic balance and multiple time scales. V: BARTOLIĆ, Juraj (ur.). *ICECOM '99 : proceedings*. Zagreb: KoREMA, 1999, str. 130-134. [COBISS.SI-ID 4870422]
- PUŠENJAK, Rudi. Computation of electromagnetic waveguide transverse resonances by using continuous finite elements. V: BONEFAČIĆ, Davor (ur.). 16th International Conference on Applied Electromagnetics and Communications, 1-3 October 2001, Dubrovnik, Croatia. *ICECOM 2001 : conference proceedings*. Zagreb: KoREMA, 2001, str. 257-264. [COBISS.SI-ID 6596630]
- PUŠENJAK, Rudi. Razvejitve pri Van der Pol-Duffingovem nihalu = Bifurcations of the Van der Pol-Duffing oscillator. *Stroj. vestn.*, 2003, letn. 49, št. 7/8, str. 370-384. [COBISS.SI-ID 8489750] JCR IF: 0.048, SE (99/106), engineering, mechanical, x: 0.61
- PUŠENJAK, Rudi, OBLAK, Maks. Incremental harmonic balance method with multiple time variables for dynamical systems with cubic non-linearities. *Int. j. numer. methods eng.*, Jan. 2004, vol. 59, iss. 2, str. 255-292. [COBISS.SI-ID 8442134] JCR IF: 1.501, SE (3/61), engineering, multidisciplinary, x: 0.57, SE (7/162), mathematics, applied, x: 0.698
- KASTREVC, Mitja, PUŠENJAK, Rudi. Fuzzy pressure control of hydraulic system with gear pump driven by variable speed induction electro-motor. *Exp. tech. (Westport Conn.)*, May/June 2005, vol. 29, no. 3, str. 57-62. [COBISS.SI-

ID 9576470]JCR IF: 0.363, SE (64/104), engineering, mechanical, x: 0.644, SE (92/110), mechanics, x: 0.96, SE (19/25), materials science, characterization & testing, x: 0.575

- PUŠENJAK, Rudi. Extended Lindstedt-Poincare method for non-stationary resonances of dynamical systems with cubic nonlinearit. *J. Sound Vib.*, July 2008, vol. 314, iss. 1/2, str. 194-216. http://dx.doi.org/10.1016/j.jsv.2008.01.002. [COBISS.SI-ID 12081430]JCR IF (2007): 1.024, SE (11/28), acoustics, x: 1.012, SE (23/107), engineering, mechanical, x: 0.706, SE (39/112), mechanics, x: 1.049
- PUŠENJAK, Rudi, OBLAK, Maks. Discussion on: "Analysis of control relevant coupled nonlinear oscillatory systems". *Eur. j. control*, 2008, vol. 14, 4, str. 283-285. http://dx.doi.org/10.3166/ejc.14.283-285. [COBISS.SI-ID 12640790]JCR IF (2007): 1.153, SE (20/52), automation & control systems, x: 0.927
- PUŠENJAK, Rudi, OBLAK, Maks, TIČAR, Igor. Nonstationary Vibration and Transition through Fundamental Resonance of Electromechanical Systems Forced by a Nonideal Energy Source. *Int. J. of Nonl. Sci. Num. Sim.*, May 2009, vol. 10, iss. 5, str. 635-657.JCR IF (2007): 5.099, SE(1/67), engineering, multidisciplinary, SE(1/165),mathematics,applied, SE(2/112)mechanics, (1/43), physics, mathematical
- PUŠENJAK, Rudi, OBLAK, Maks, TIČAR, Igor. Modified Lindstedt-Poincare method with multiple time scales for combination resonance of damped dynamical systems with strong linearities. *Int. J. of Nonl. Sci. Num. Sim.*, May 2010, vol. 11, no. 3, str. 173-201. [COBISS.SI-ID 13917718], [JCR, SNIP, WoS].
- PUŠENJAK, Rudi, OBLAK, Maks, The Control of Nonlinear Oscillatory Systems with Delay – Upravljanje nelinearnih nihajočih sistemov z zakasnitvami, *Anali PAZU*, 2013, vol. **3**(1), str. 15-24. [COBISS.SI-ID 554230]
- PUŠENJAK, Rudi, TIČAR, Igor, OBLAK, Maks.Self-excited oscillations and Fuel Control of a Combustion Process in a Rijke Tube. *International Journal for Nonlinear Sciences and Numerical Simulation*, 2014, vol. 15(2), str. 87-106. [COBISS.SI-ID 17621526], [JCR, SNIP, WoS].
- PUŠENJAK, Rudi, TIČAR, Igor. Combustion Processes with External Harmonic Excitation Using Extended Lindstedt-Poincare Method with Multiple Time Scales. V: Developments in Combustion Technology. ISBN 978-953-51-4679-7 (v tisku).