Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Mehatronika I
Course title:	Mechatronics I

Študijski program Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Inženiring in vozila		drugi	tretji
Engineering and vehicles		second	third

Vrsta predmeta / Course type	obvezni/obligatory
Univerzitetna koda predmeta / University course code:	**VS_11012**

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
60	-	30	15	-	105	7

Nosilec predmeta / Lecturer:	Red. prof. dr. Rudolf Pušenjak

Jeziki / Languages:	**Predavanja /Lectures:**	slovensko/slovenian
	Vaje / Tutorial:	slovensko/slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
– vpis drugi letnik študija,	– inscription in the second year of study,

Vsebina:	**Content (Syllabus outline):**
Predavanja:	*Lectures*
– Opredelitev mehatronike, problem sinteze v mehatroniki, procesna analiza mehatronskih sistemov.	Definition of mechatronics, the problem of synthesis in mechatronics, the process analysis of mechatronic systems.
– Modeliranje mehatronskih sistemov v časovnem in slikovnem prostoru. Spremenljivke stanja. Linearizacija statičnih karakteristik. Prenosna funkcija lineariziranega sistema.	– Modeling of mechatronics systems in time domain and in the image space. State space variables. Linearization of static characteristics. Transfer function of linearized system.
– Senzorji v mehatronskih sistemih. Stopnja integracije senzorjev, karakteristične veličine senzorjev. Fizikalni principi merjenja kinematičnih in dinamičnih veličin. Merilniki pomika, hitrosti in pospeškov. Merilniki sile, tlaka in vrtilnih momentov. Merilniki temperature.	– Sensors in mechatronics systems. The degree of integration of sensors, characteristic quantities of sensors. Physical principles of measurement of kinematic and dynamic quantities. Measuring devices of displacement, velocity and acceleration. Measuring devices of force, pressure and torque. Measurement devices of temperature.
– Aktuatorji, zgradba aktuatorjev in osnove delovanja. Elektromehanski aktuatorji, pnevmatski aktuatorji, hidravlični aktuatorji, piezoelektrični in magnetostriktivni aktuatorji.	– Actuators, structure of actuators and principles of operation. Electromechanical actuators, pneumatic actuators, hydraulic actuators, piezoelectric and magnetostrictive actuators.
– Obdelava procesnih podatkov v realnem času. Osnovne strukture časovno in dogodkovno vezane obdelave podatkov. Večopravilnost in procesiranje z več	– Real-time data processing. Basic structures of data processing with time and event constraints. Multitasking and multiprocessing. Time- and event scheduling. Process synchronization.

procesorji. Časovno in dogodkovno dodeljevanje. Sinhronizacija procesov. – Kinematika mehanskih sistemov z več telesi, manipulatorjev in robotov. Denavit-Hartenbergova notacija. Modeliranje in preračun industrijskega robota. *Seminarske in laboratorijske vaje:* – Poglobitev teoretičnih znanj na seminarskih vajah z reševanjem praktičnih primerov stroke. – Pridobitev praktičnih izkušenj na laboratorijskih vajah s programiranjem in upravljanjem mehatronskih sistemov.	– Kinematics of mechanical systems with multiple bodies, manipulators and robots. Denavit-Hartenberg notation. Modeling and computation of an industrial robot. *Tutorials and Lab works* – Deepening of the theoretical knowledge on tutorials by solving practical examples in the field. – The acquisition of practical experiences in lab works by programming the mechatronic systems and their control.

Temeljna literatura in viri / Readings:

E-gradiva predmeta / E-Course material

- R. Pušenjak, M. Oblak, Mehatronika I, elektronsko učno gradivo, Fakulteta za industrijski inženiring Novo mesto, 2018.
- R. Pušenjak, Navodila za izdelavo seminarske naloge pri predmetu Mehatronika I, elektronsko učno gradivo, Fakulteta za industrijski inženiring Novo mesto, 2017.

Priporočena literatura/ Recommended readings:

- B.Heimann, Mechatronik, Fachbuchverlag Leipzig im Carl Hanser Verlag, 199.8
- R. Isermann, Mechatronic Systems: Fundamentals, Springer, 2005.
- W.Höger, Mechatronik, Hochshule München, 2008.

Cilji in kompetence:	**Objectives and competences:**
Cilji – Seznanitev z osnovnimi pojmi mehatronike in mehatronskih sistemov. – Prikazati namen in uporabnost sitemov in novih pristopov pri gradnji tovrstnih sistemov. – Pregled samih sistemov, kakor tudi pojasnila potrebna za razumevanje delovanja in sklapljanja posameznih enot v celovit sistem. **Kompetence** – sposobnost evidentiranja problema in njegove analize ter predvidevanja operativnih rešitev v tehnološkem smislu, – sposobnost obvladanja standardnih razvojnih metod, postopkov in procesov, – sposobnost uporabe pridobljenega teoretičnega znanja v praksi, – avtonomnost v strokovnem delu na področju tehnologij in 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 informacijsih in komunikacijskih tehnologij na področju mehatronike.	**Objectives** – The conquest of basic concepts of mechatronic and mechatronic systems. – The goal is to show the student the purpose and applicability of new approaches in building such systems. – The overview of components of mechatronic system is presented and their operation is explained in details. **Competences** – ability to use the standard development methods, procedures and processes, – ability to apply acquired theoretical knowledge in practice, – professional autonomy in the field of technologies and 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:**
Študent: – pozna in razume osnovno razdelitev mehatronskih sistemov, – jih zna razvrščati v posamezne skupine in podskupine, – pozna osnovne lastnosti komponent in njihovo namembnost, – se seznani z omejitvami pri sestavljanju sistemov, – zna načrtovati, uporabljati standarde in literaturo.	Student: – understands the basic classification of mechatronics systems, – knows the classification into individual groups and subgroups, – knows the basic properties of the components and their purpose, – is acquainted with the limitations in constructing 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, – seminarske vaje za poglabljanje teoretičnih osnov in reševanje praktičnih problemov stroke – individualno in skupinsko delo s študenti v obliki konzultacij, – laboratorijske vaje, ki potekajo v ustrezno opremljenem laboratoriju. Predmet je oblikovan na kombinirani način študija, ki vključuje aktivnosti preko elektronskega (on-line) okolja: te aktivnosti so sestavljene iz samostojnih in skupinskih aktivnosti z uporabo učnega okolja Moodle in drugih elektronskih vsebin. Praviloma vključujejo diskusije v forumih, spletne strani, ogled posnetih predavanj in vaj, preverjanje znanja, odgovori na vprašanja, iskanje po spletu (bazah) itd.	– lectures with active attendance of students, which incorporate discussions, answers on the questions and solving of exercises with application of the contemporary pedagogical aids – tutorials with deepening of the theoretical knowledge and solving problems, which appear in practice – individual and collective work in the form of consultations, – lab works, which are performed in a suitable equipped laboratory. The course is designed as blended learning that includes online activities: Online activities consist of independent and group activities using the LMS Moodle and other electronic or online content. Activities usually include discussions in forums, websites, viewing of recorded lectures and tutorials, assessments, answering questions, searching the web (databases), etc.

Načini ocenjevanja:	**Delež /Weight (%)**	**Assessment:**
Pogoj za pristop k pisnemu izpitu so opravljene laboratorijske vaje.		The prerequisite for accession to the exam is performance of lab works.
– ocena laboratorijskih vaj	**20%**	– the grade of lab work
– seminarska naloga	**40%**	– seminar work
– pisni izpit	**40%**	– written exam
Ocenjevalna lestvica je skladna z ECTS in Pravilnikom o preverjanju in ocenjevanju znanja FINI NM.		Evaluation scale in accordance with ECTS and the Rules on the Evaluation and Assessment of Knowledge FINI NM.

Reference nosilca / Lecturer's references:

– PUŠENJAK, Rudi, OBLAK, Maks. Finite element method using continous elements with constant geometries. V: ROBINSON, John (ur.). *Quality assurance in FEM technology : [proceedings of the Fifth world congress sponsored by ISTEL England]*. Okehampton: Robinson and Associates. cop. 1987, str. 369-378. [COBISS.SI-ID 443140]

– PUŠENJAK, Rudi, OBLAK, Maks. Design of axisymmetric electron optical systems with use of continuous and fully discretized finite elements. V: *FEMCAD-88 : proceedings of the Fourth SAS-World Conference, Paris, 17-19 October 1988*, (Technology transfer series). Gournay-sur-Marne: IITT-International. 1988, str. 256-263. [COBISS.SI-ID 7316484]

- PUŠENJAK, Rudi, OBLAK, Maks. The use of continuous finite elements in electron optics. V: TANAKA, Masataka (ur.), CRUSE, Thomas A. (ur.). *Boundary element methods in applied mechanics : proceedings of the First Joint Japan/US Symposium on Boundary Element Methods, Tokyo, Japan, 3-6 October 1988*. Oxford [etc.]: Pergamon Press. 1988, str. 47-52. [COBISS.SI-ID 7315972]
- PUŠENJAK, Rudi, OBLAK, Maks. Continuous finite element model for solution of paraxial ray equation in electron optics. V: *Proceedings*. [S.l.]: American Academy of Mechanics. 1989, str. 316-319. [COBISS.SI-ID 7333636]
- 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: G. KYPRIANIDIS, Konstantinos (ur.), SKVARIL, Jan (ur.). *Developments in combustion technology*. Rijeka: InTech. 2016, str. 372-396. [COBISS.SI-ID 19938838]