Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

| UČNI NAČRT PREDMETA / *COURSE SYLLABUS* | |
|---|---|
| **Predmet:** | Energetski sistemi v vozilih |
| ***Course title*:** | Energy systems in vehicles |

| **Študijski program** *Study programme and level* | **Študijska smer** *Study field* | **Letnik** *Academic year* | **Semester** *Semester* |
|---|---|---|---|
| Inženiring in avtomobilska industrija | | drugi | |
| Engineering and Automotive Industry | | second | |

| **Vrsta predmeta / *Course type*** | Izbirni | Optional |
|---|---|---|

| **Univerzitetna koda predmeta / *University course code:*** | **MAG_21013** |
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| **Predavanja** *Lectures* | **Seminar** *Seminar* | **Sem. vaje** *Tutorial* | **Lab. vaje** *Laboratory work* | **Teren. vaje** *Field work* | **Samost. delo** *Individ. work* | **ECTS** |
|---|---|---|---|---|---|---|
| 45 | - | 45 | - | - | 150 | 8 |

| **Nosilec predmeta / *Lecturer:*** | **Prof. dr. Rudi Pušenjak** |
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| **Jeziki / *Languages:*** | **Predavanja / *Lectures*:** | **Vaje / *Tutorial:*** |
|---|---|---|
| | Slovenski | Slovenski |
| | Slovenian | Slovenian |

| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | ***Prerequisits:*** |
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| – pogoj za opravljanje študijskih obveznosti je vpis v 2. letnik študija. | – Prerequisite for performing the study obligations is enrolment in the 2nd year of study. |

| **Vsebina:** | ***Content (Syllabus outline):*** |
|---|---|
| – Osnove motoroznanstva, osnove energetskih sistemov v vozilih, pregled elektromotorskih pogonov za uporabo v vozilih.<br>– Energetski sistemi vozil na osnovi motorjev z notranjim izgorevanjem:<br>- principi delovanja, energetska enačba posameznih tipov motorjev, izkoristki, dosedanji razvoj in bodoči trendi,<br>- optimizacija motorjev, elektronske krmilne naprave, komunikacijski sistemi v vozilih.<br>– Energetski sistemi v vozilih s hibridnim pogonom:<br>- razvoj hibridnih sistemov, prednosti in slabosti uporabe hibridnih pogonov v vozilih,<br>- konfiguracije hibridnih energetskih sistemov: serijski, paralelni in »mehki« hibridni sistemi,<br>- hibridni energetski sistemi glede na vrsto elektromotorjev,<br>- elektronski krmilniki v hibridnih vozilih,<br>- tipi hibridnih vozil in njihova integracija.<br>– Energetski sistemi v električnih vozilih:<br>- razvoj električnih vozil, prednosti in slabosti uporabe električnih pogonov v vozilih,<br>- konfiguracije električnih energetskih sistemov in njihov vpliv na ostale sklope v vozilih, na oblikovanje potniškega prostora in na design bodočih vozil, vplivi na varnost,<br>- razvrstitev električnih vozil glede na vrsto elektromotorjev (za pogon preko gredi oziroma direktni notranji kolesni pogon),<br>- elektronski krmilniki v električnih vozilih,<br>- baterije, akumulatorji, sistemi polnjenja,<br>- tipi hibridnih vozil in njihova integracija,<br>- infrastruktura, povezana z električnimi vozili.<br>– Alternativni energetski sistemi v vozilih:<br>- vozila s pogonom na osnovi uporabe vodika,<br>- vozila z gorivnimi celicami,<br>- vozila in sončna energija,<br>- ostali alternativni viri energije v vozilih bodočnosti. | – Engine fundamentals, fundamentals of energy systems in vehicles and survey of electromotor drives for automotive applications<br>– Energy systems of vehicles based on engines with internal combustion:<br>- operating principles, the energy equation of individual engine types, efficiency, the current development and future trends,<br>- engine optimization, electronic control units, vehicle communication systems.<br>– Energy systems of vehicles with hybrid engine:<br>- development of hybrid systems, advantages and shortcomings of the use of hybrid engines in vehicles,<br>- configurations of hybrid energy systems: serial, parallel and soft hybrid systems,<br>- hybrid energy systems in respect to kind of electromotor drives,<br>- electronic control units in hybrid vehicles,<br>- types of hybrid vehicles and their integration.<br>– Energy systems in electric vehicles:<br>- development of electric vehicles, advantages and shortcomings of the use of electric engines in vehicles,<br>- configurations of electric energy systems and their impact on other assemblies in vehicles, impact on the design of the driver's compartment as well as on the design of the future vehicles, impact on the security,<br>- classification of electric vehicles based on the type of electromotor drive (for power transmission through shaft or direct inner wheel drive),<br>- electronic control units in electric vehicles,<br>- baterries, charging systems,<br>- types of hybrid vehicles and their integration,<br>- infrastructure associated with electric vehicles.<br>– Alternative energy systems in vehicles:<br>- hydrogen internal combustion engine vehicles,<br>- fuel-cell vehicles,<br>- solar vehicles,<br>- other alternative energy sources in the future vehicles. |

**Temeljni literatura in viri / *Readings:***

**E-gradiva predmeta | E-Course material**

– Pušenjak R. *Elektromotorski pogoni za električna vozila.* Dodatno učno gradivo za izdelavo seminarske naloge. Fakulteta za industrijski inženiring Novo mesto, 2019.

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| Velja od: 1. 10. 2019 | Sprejel: Senat FINI Novo mesto |

Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

**Priporočljiva literatura / *Recomended Textbooks***


- Stone, R. (2012). *Introduction to Internal Combustion Engines*, 4th edition. Palgrave: Macmillan. ISBN 9780230576636.
- Moran and Shapiro. (2006). *Fundamentals of Engineering Thermodynamics*, 5th Edition. John Wiley&Sons Ltd. ISBN 978-0-470-03037-0.
- Ehsani, M., Gao, Y., & Emadi, A. (2010). *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory and Design*, 2nd Edition. Taylor&Francis Group: CRC Press. ISBN 978-1-4200-5398-2.
- ASME. (2008). *Vision for Mechanical Engineering*. A report of the Global Summit on the Future of Mechanical Engineering. ASME: New York. www.asme.org
- CLEPA.(2009). R&D. *Priorities for the Greening of Vehicle and Road Transport.* Brussels. www.clepa.eu
- ERTRAC. (2006). *Strateški razvojni načrt 2007-2013*. Slovenska tehnološka platforma za vozila, ceste in promet. www.ertrac.org
- Husain, I. (2003). *Electric and hybrid vehicles – Design Fundamentals*. CRC Press.
- Reding, V. (2006). *The Intelligent Car Initiative: raising awareness of ICT for Smarter, Safer and Cleaner vehicle*. Speech delivered at the Intelligent Car Launching Event: Brussels.
- eSafety Forum WG RTD. (2006). *Stakeholders' Contribution to the Development of FP7 Workprogramme on ICT for Mobility*. eSafety Forum Working Group RTD.
- Arem, B. van, Driever, H., Feenstra, P., Ploeg, J., Klunder, G., Wilmink, I., Zoutendijk, A., & Papp, Z. (2007). *Design and evaluation of an Integrated Full-Range Speed Assistant*. TNO Report 2007-D-R0280/B. Delft.
- F. Salazar, Internal Combustion Engines, University of Notre Dame, 1998. https://www3.nd.edu/~msen/Teaching/DirStudies/**Engines**.pdf
- S. M. Veres, N. K. Lincoln and L. Molnar, Control engineering of autonomous cognitive vehicles – a practical tutorial, 2011. www.eucognition.org/.../control-engineering-of-**autonomous**-cognitiv...
- ACEA – Association des Constructeurs Europeans d'Automobiles.
- EUROCAR - European Council for Automotive R&D.
- CLEPA - European Association of Automotive Suppliers.
- ERTRAC, European Road Transport Research Advisory Council, Slovenska tehnološka platforma za vozila, ceste in promet.


**Cilji in kompetence:** ***Objectives and competences:***

| ***Cilji*** | ***Objectives*** |
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| – spoznavanje dosedanjega razvoja energetskih sistemov v vozilih, s poudarkom na avtomobilih,<br>– seznanitev s sodobnimi energetskimi sistemi v vozilih ter trendi bodočega razvoja,<br>– seznanitev z bodočimi tehnologijami in energetskimi sistemi, ki se bodo uporabljali v vozilih bodočnosti, vplivi na razvoj ostalih sistemov v vozilih ter vplivi na design bodočih vozil s poudarkom na avtomobilih,<br>– seznanitev z bodočimi oblikami mobilnosti in uporabe vozil, seznanitevz vplivom na infrastrukturo, družbo in okolje,<br>– razvijanje sposobnosti uporabe znanstvenih metod za predvidevanje bodočih trendov razvoja,<br>– razvijanje sposobnosti analize lastnega arhiviranega gradiva, rezultatov raziskav ter konkurenčnih rešitev,<br>– razvijanje sposobnosti analize zakonodaje, regulativ in usmeritev, | – learning about the present development of vehicle energy systems with emphasis on cars,<br>– learning about advanced vehicle energy systems in the light of future trends,<br>– learning about future technologies and energy systems, applied in future vehicles, about impacts on development of other vehicle systems as well as on the design of vehicles and especially on the design of cars,<br>– learning about future kinds of mobilityand use of vehicles, about impact on the infrastructure, society and environment,<br>– ability to apply scientific methods in prediction of future development trends,<br>– ability to analyze own archived knowledge, to examine research results as well as competitive solutions,<br>– ability to analyze law regulations and guidelines,<br>– ability for team work and implementation of the projects. |

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|---|---|
| – razvijanje sposobnosti timskega in projektnega dela.<br>***Kompetence***<br>– sposobnost celovitega razumevanja delovanja energetskih sistemov v vozilih,<br>– sposobnost analiziranja trendov na področju energetskih sistemov v vozilih,<br>– sposobnost sodelovanja v raziskavah na področju energetskih sistemov v vozilih,<br>– sposobnost uporabe pridobljenega teoretičnega znanja v praksi,<br>– sposobnost sodelovanja v razvoju in napredku tehnologije,<br>– kooperativnost, usposobljenost za timsko delo,<br>– sposobnost vključevanja v RR projekte in sodelovanja z inštitucijami znanja,<br>– sposobnost uporabe znanja interdisciplinarnih ved. | ***Competences***<br>– ability of understanding the operating principles of vehicles,<br>– ability to analyze trends in the area of vehicle energy systems,<br>– ability to participate in vehicle energy systems research,<br>– ability to apply the gained theoretical knowledge in practice,<br>– ability to participate to the development and advance of technology<br>– cooperability and ability to perform team work,<br>– ability to join into research projects and to cooperate with research institutions,<br>– ability to apply knowledge of interdisciplinary sciences. |

**Predvideni študijski rezultati:** ***Intended learning outcomes:***

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| ***Študent/študentka:***<br>– ob seznanitvi z najnovejšimi tehnološkimi dosežki in predvidevanji oblikuje pogled v prihodnji razvoj energetskih sistemov v vozilih,<br>– spozna in doume pomen stalnih tehnoloških izboljšav v razvoju vozil na področju energetskih sistemov,<br>– ustvarja si življenjski pogled, ki poleg zelo pomembnih družbenih in humanistični ved ter kulture, visoko ceni in spoštuje dosežke in spoznanja s področij energetike v vozilih,<br>– poglabljanje znanja na področju energetskih sistemov vzpodbuja študente k novim izzivom in možnostim osebnega zadovoljstva na novih službenih dolžnostih, velike možnosti napredovanja v karieri pa tudi možnosti mednarodnega sodelovanja. | ***Student:***<br>– is forming in the learning of the newest technological achievements and expectations an insight into the future development of the energy systems in vehicles,<br>– grasp the importance of permanent technological improvements in the development of vehicles in the field of energy systems,<br>– is making a life view, which in addition to the very important social and humanistic sciences and culture, highly values and respects the achievements and knowledge in the field of energy systems in vehicles,<br>– deepening knowledge in the field of energy systems encourages students to new challenges and possibilities of personal satisfaction in the new official duties, the great career prospects as well as the possibilities of international cooperation. |

| **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,<br>– seminarske naloge in vaje,<br>– razvijanje samostojnega razmišljanja in osebnih pobud v širokem spektru ustvarjalnega in inovativnega dela,<br>– priprava možnostnih študij (Feasibility Studies) za posamezne razvojne metode,<br>– poznavanje in uporaba raznovrstne strokovne in patentne literature ter praktična uporaba dosegljive dokumentacije iz knjig, revij, interneta in arhivov,<br>– strokovne ekskurzije in ogledi izbranih podjetij.<br><br>Predmet je oblikovan na kombinirani način študija, ki vključuje aktivnosti preko elektronskega (on-line) okolja:<br>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<br>– seminar work , which serves to the deepening of the theoretical knowledge andsolving problems, which appear in practice,<br>– the development of a stand-alone thinking and personal initiatives in a broad spectrum of creative and innovative work,<br>– preparation of feasibility studies for individual development methods,<br>– knowledge and use of a variety of technical and patent literature, and practical application of available documentation from books, magazines, the Internet and archives,<br>– professional excursions in selected enterprises<br><br>The course is designed as blended learning that includes online activities:<br>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.<br>. |

| **Načini ocenjevanja:** | **Delež/Weight (%)** | **Assessment:** |
|---|---|---|
| Pogoj za pristop k izpitu je pozitivno ocenjena seminarska naloga.<br><br>– seminarska naloga<br>– pisni izpit<br>– ustni izpit<br><br>Ocenjevalna lestvica je skladna z ECTS in Pravilnikom o preverjanju in ocenjevanju znanja FINI NM. | <br><br>30%<br>40%<br>30% | The prerequisite for accession to the exam is positive grade of the seminar work.<br><br>– seminar work<br>– written exam<br>– oral exam<br><br>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. Rešavanje Helmholtzove (talasne) jednačinemetodom konačnih elemenata. Elektrotehnika (Beogr.), 1978, 27, št. 12, str. 1789-1795.
– PUŠENJAK, Rudi, OBLAK, Maks. Finite element method using continous elementswith constant geometries. V: ROBINSON, John (ur.). Quality assurance in FEMtechnology : [proceedings of the Fifth world congress sponsored by ISTEL England].Okehampton: Robinson and Associates, cop. 1987, str. 369-378.
– PUŠENJAK, Rudi, OBLAK, Maks. The use of continuous finite elements in electronoptics. V: TANAKA, Masataka (ur.), CRUSE, Thomas A. (ur.). Boundary elementmethods in applied mechanics : proceedings

of the First Joint Japan/US Symposium onBoundary Element Methods, Tokyo, Japan, 3-6 October 1988. Oxford [etc.]: PergamonPress, 1988, str. 47-52.

- PUŠENJAK, Rudi, OBLAK, Maks. Design of axisymmetric electron optical systemswith 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.
- PUŠENJAK, Rudi, OBLAK, Maks. Continuous finite element model for solution ofparaxial ray equation in electron optics. V: Proceedings. [S.l.]: American Academy ofMechanics, 1989, str. 316-319.
- PUŠENJAK, Rudi, OBLAK, Maks. Numerische Lösung einiger Torsionsprobleme unterAnwendung von kontinuierlichen Elementen. Z. angew. Math. Mech., 72 (1992), 6 ; str.T 489-493. JCR IF (1994): 0.17, SE (54/61), mechanics, x: 0.83, SE (71/85),mathematics, applied, x: 0.484
- PUŠENJAK, Rudi. Nonlinear almost periodic analysis of FET amplifiers by incrementalharmonic balance and multiple time scales. V: BARTOLIĆ, Juraj (ur.). ICECOM '99 :proceedings. Zagreb: KoREMA, 1999, str. 130-134.
- PUŠENJAK, Rudi. Computation of electromagnetic waveguide transverse resonances byusing continuous finite elements. V: BONEFAČIĆ, Davor (ur.). 16th InternationalConference on Applied Electromagnetics and Communications, 1-3 October 2001,Dubrovnik, Croatia. ICECOM 2001 : conference proceedings. Zagreb: KoREMA,2001, str. 257-264
- PUŠENJAK, Rudi. Razvejitve pri Van der Pol-Duffingovem nihalu = Bifurcations of theVan der Pol-Duffing oscillator. Stroj. vestn., 2003, letn. 49, št. 7/8, str. 370-384.JCR IF: 0.048, SE (99/106), engineering, mechanical, x: 0.61
- PUŠENJAK, Rudi, OBLAK, Maks. Incremental harmonic balance method withmultiple time variables for dynamical systems with cubic non-linearities. Int. j. numer.methods eng., Jan. 2004, vol. 59, iss. 2, str. 255-292 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 systemwith gear pump driven by variable speed induction electro-motor. Exp. tech. (WestportConn.), May/June 2005, vol. 29, no. 3, str. 57-62.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 resonancesof dynamical systems with cubic nonlinearit. J. Sound Vib., July 2008, vol. 314, iss. 1/2,str. 194-216.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 andTransition through Fundamental Resonance of Electromechanical Systems Forced by aNonideal 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].
- 16.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]