# MOTORJI Z NOTRANJIM ZGOREVANJEM IN ELEKTROMOBILNOST

# UČNI NAČRT PREDMETA/COURSE SYLLABUS

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| **Predmet:** | Motorji z notranjim zgorevanjem in elektromobilnost |
| **Course title:** | INTERNAL COMBUSTION ENGINES AND ELECTROMOBILITY |
| **Članica nosilka/UL Member:** | UL FS |

| **Študijski programi in stopnja** | **Študijska smer** | **Letnik** | **Semestri** | **Izbirnost** |
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| Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni | Energetsko strojništvo (smer) | 3. letnik | 1. semester | obvezen |

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| **Univerzitetna koda predmeta/University course code:** | 0562726 |
| **Koda učne enote na članici/UL Member course code:** | 3027-V |

| **Predavanja /Lectures** | **Seminar /Seminar** | **Vaje /Tutorials** | **Klinične vaje /Clinical tutorials** | **Druge oblike študija /Other forms of study** | **Samostojno delo /Individual student work** | **ECTS** |
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| 30 | | 30 | | | 40 | 4 |

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| **Nosilec predmeta/Lecturer:** | Tomaž Katrašnik |
| **Vrsta predmeta/Course type:** | Izbirni strokovni predmet /Elective specialised course |

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| **Jeziki/Languages:** | Predavanja/Lectures: | Slovenščina |
| | Vaje/Tutorial: | Slovenščina |

| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | **Prerequisites:** |
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| Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program. | Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme. |

| **Vsebina:** | **Content (Syllabus outline):** |
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| 1. Predavanje:<br>- Primeri pogonov v prometu in identifikacija komponent pogonov;<br>- Razvrstitev komponent pogonov (prenosniki moči, pretvorniki energije, naprave za shranjevanje energije);<br>- Raba energije in neposredni ter posredni izpusti onesnažil pogonov.<br>2. Predavanje:<br>- Tehnološke smernice in zahteve razvoja motorjev z notranjim zgorevanjem in elektrificiranih hibridnih ter električnih pogonskih sistemov vozil;<br>- Energijski tokovi v pogonih in osnovni pregled izkoristkov komponent pogonov vozil;<br>- Ragonov diagram.<br>Motorji z notranjim zgorevanjem (MNZ):<br>3. Predavanje:<br>- Energijske pretvorbe v MNZ;<br>- Teoretični procesi v MNZ (določitev izkoristka, delovne sposobnosti) in njihova primerjava s procesi v realnih MNZ;<br>- Metode za izboljšanje izkoristka motorjev.<br>4. Predavanje:<br>- Zasnove batnih MNZ in njihove značilnosti;<br>- Kinematika bata in uravnoteženje prostih sil in navorov.<br>5. Predavanje: Motorji s prisilnim vžigom (Ottovi motorji):<br>- Zasnova in komponente;<br>- Priprava gorljive zmesi;<br>- Vžig zmesi in zgorevanje.<br>6. Predavanje: Motorji s samovžigom (dizelski motorji):<br>- Zasnova in komponente;<br>- Priprava gorljive zmesi;<br>- Vžig zmesi in zgorevanje.<br>7. Predavanje: Motorji z naprednimi | 1. Lecture:<br>- Examples of powertrains in transport and identification of their components,<br>- Classification of powertrains components, (power transmissions, energy converters, energy storage devices),<br>- Use of energy and direct and indirect emissions of vehicle’s powertrains.<br>2. Lecture:<br>- Technology guidelines and R&D requirements of internal combustion engines and electric hybrid and fully electric powertrains,<br>- Energy flows in powertrains and efficiencies of powertrain components,<br>- Ragone plot.<br>Internal combustion engines (ICE):<br>3. Lecture:<br>- Energy conversion paths in ICEs,<br>- Theoretical processes in ICEs (evaluation of efficiency and indicated mean effective pressure) and their interrelation to processes in real ICEs,<br>- Methods for increasing efficiency of ICEs.<br>4. Lecture:<br>- Types and designs of piston ICEs and their characteristics and performances,<br>- Kinematics of the piston motion in piston engines and balancing free forces and moments.<br>5. Lecture: Spark ignition (SI) engines (Otto engines)<br>- Design and components,<br>- Mixture preparation,<br>- Ignition and combustion.<br>6. Lecture: Compression ignition (CI) engines (Diesel engines)<br>- Design and components,<br>- Mixture preparation,<br>- Ignition and combustion. |

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| procesi zgorevanja (LTC, CAI…):<br>- Zasnova in komponente;<br>- Priprava gorljive zmesi;<br>- Vžig in zgorevanje.<br>8. Predavanje: Mehanizmi tvorbe izpustov onesnažil MNZ (dušikovi oksidi, ogljikov monoksid, nezgoreli ogljikovodiki, delci).<br>9. Predavanje: Sistemi in naprave za naknadno obdelavo plinskih onesnažil in delcev (TWC, DOC, SCR, LNT, DPF, GPF).<br>10. Predavanje:<br>- Izmenjava delovnega medija;<br>- Mehanske izgube v MNZ;<br>- Termoregulacija MNZ.<br>11. Predavanje:<br>- Prisilno polnjenje MNZ (valovna dinamika, mehansko prisilno polnjenje, prisilno polnjenje s turbopolnilnikom, kombinacije metod za prisilno polnjenje);<br>- Zmogljivosti MNZ.<br>Elektromobilnost:<br>12. Predavanje: Električni stroji:<br>- Osnove delovanja električnih strojev;<br>- Izvedbe električnih strojev in njihove značilnosti ter zmogljivosti.<br>13. Predavanje: Baterije in gorivne celice:<br>- Osnove delovanja baterij in gorivnih celic;<br>- Izvedbe baterij in njihove značilnosti ter zmogljivosti;<br>- Izvedbe gorivnih celic in njihove značilnosti ter zmogljivosti;<br>- Dejavniki staranja baterij in gorivnih celic.<br>14. Predavanje:<br>- Topologije pogonov vozil (MNZ, električni pogoni, hidravlični pogoni, hibridni pogoni, priključni hibridni pogoni, kombinirani pogoni);<br>- Izbira ustreznih pogonov z ozirom na predviden način uporabe vozila.<br>Refleksija in sinteza:<br>15. Predavanje:<br>- Refleksija in povezovanje vsebin;<br>- Učinkovitost energijskih pretvorb v različnih pogonih vozil z ozirom na tip vozila in način uporabe – analiza | 7. Lecture: Engines with advanced combustion concepts (LTC, CAI…)<br>- Design and components,<br>- Mixture preparation,<br>- Ignition and combustion.<br>8. Lecture: Mechanisms of pollutant emission formation in ICEs (nitrogen oxides, carbon monoxide, unburned hydrocarbons, particles).<br>9. Lecture: Exhaust after-treatment devices for gaseous pollutants and particles (TWC, DOC, SCR, LNT, DPF, GPF).<br>10. Lecture:<br>- Exchange of the working media,<br>- Mechanical losses in piston ICEs,<br>- Thermoregulation of piston ICEs.<br>11. Lecture:<br>- Supercharging of piston ICEs (wave dynamics, mechanical supercharging, turbocharging, combined charging),<br>- Performance characteristics of piston ICEs.<br>Electromobility:<br>12. Lecture: Electrical machines<br>- Basics principles of electrical machines,<br>- Classification and design of electrical machines and their characteristics and performances.<br>13. Lecture: Batteries and fuel cells<br>- Basic principles of batteries and fuel cells,<br>- Classification of batteries, their characteristics and performances,<br>- Classification of fuel cells, their characteristics and performances,<br>- Degradation mechanisms of batteries and fuel cells.<br>14. Lecture:<br>- Topologies of vehicle propulsion systems (internal combustion powertrains, battery electric powertrains, hydraulic drives, hybrid powertrains, combined powertrains),<br>- Selection of appropriate powertrains with respect to the intended use of the vehicle.<br>Reflection and synthesis:<br>15. Lecture:<br>- Reflection and integration of content, |

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| primerov dobrih praks in analize potencialov za nadaljnja izboljšanja pogonov prihodnosti. | - Energy conversion efficiency of vehicle’s powertrains with respect to the vehicle type and intended use of the vehicle – analysis of good practices and analysis of potential further improvements of future powertrains. |

**Temeljna literatura in viri/Readings:**


1. Taylor, C.F.: The Internal combustion engine in theory and praxis, Vol.1 – thermodynamics, fluid flow, performance, The MIT Pres, Massachusetts, 1986, ISBN 0-262-20051-1
2. Heywood,J.B.: Internal combustion engine fundamentals, McGraw-Hill, N.York,1988,ISBN 0-07-028637-X
3. Guzzella L, Sciarretta A.: Vehicle Propulsion Systems - Introduction to Modeling and Optimization, 2nd ed., Springer, 2007, ISBN 978-3-540-74691-1


| **Cilji in kompetence:** | **Objectives and competences:** |
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| Cilji:<br>1. Razumeti teoretične osnove in metode vrednotenja procesov v motorjih z notranjim zgorevanjem<br>2. Spoznati različne zasnove motorjev z notranjim zgorevanjem in razumeti njihove značilnosti in prednosti<br>3. Spoznati in razumeti delovanje različnih metod za prisilno batnih motorjev z notranjim zgorevanjem<br>4. Spoznati pristope za zmanjševanje izpustov onesnažil in sisteme in naprave za naknadno obdelavo izpušnih plinov<br>5. Razumeti teoretične osnove in način delovanja komponent elektrificiranih pogonskih sistemov vozil (baterije, gorivne celice, električni stroji)<br>6. Spoznati interakcije in soodvisnosti različnih gradnikov sodobnih pogonskih sistemov vozil<br>7. Spoznati in razumeti delovanje elektrificiranih in električnih pogonskih sistemov vozil<br>8. Spoznati različne zasnove elektrificiranih pogonskih sistemov vozil in razumeti njihove značilnosti in prednosti<br>9. Znati določiti najustreznejšo topologijo pogona in značilnosti komponent pogona z ozirom na | Objectives:<br>1. Understand the theoretical foundations and characterisation methods of processes in internal combustion engines<br>2. To know different designs of internal combustion engines and to understand their characteristics and advantages<br>3. To know and to understand working principles of different supercharging methods of internal combustion engines<br>4. Understand approaches for reduction of pollutant emissions and exhaust gas after-treatment devices<br>5. To understand theoretical basis and working principles of components of electrified powertrains (batteries, fuel cells, electric machines)<br>6. To know and to understand interactions in interdependencies of components in advanced vehicle powertrains<br>7. To know and to understand working principles of electrified and fully electric powertrains<br>8. To know different topologies of electrified powertrains and to understand their characteristics and advantages |

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| namen uporabe<br>10. Razumeti pristope za razvoj naprednih-okolju prijaznejših in učinkovitejših pogonskih sistemov vozil<br><br>Kompetence:<br><br>1. Usposobljenost za vodenje tehnološke enote ali projekta na področju pogonskih sistemih vozil (S7-PAP).<br>2. Razumevanje fizikalnih pojavov in procesov v pogonskih sistemih vozil (P1-PAP)<br>3. Obvlada temeljna strokovna znanja na področju komponent in sistemov pogonskih sistemih vozil (P3-PAP)<br>4. Obvlada specifična znanja na področju komponent in sistemov pogonskih sistemih vozil, ki omogočajo aplikativna, inženirska in strokovno organizacijska dela (P8-PAP, P9-PAP). | 9. To know how to define most adequate topology of powertrain with respect of the intended use of the vehicle<br>10. Understand approaches for development of advanced-environmentally friendly and efficient vehicle propulsion systems<br><br>Competencies:<br><br>1. The ability to manage a technological unit or project in the field of vehicle propulsion systems (S7-PAP)<br>2. Understanding the laws of physics and the phenomena and processes in vehicle propulsion systems (P1-PAP)<br>3. Mastering the fundamental specialised knowledge in the field of components and systems related to vehicle propulsion systems (P3-PAP)<br>4. Mastering specific knowledge in the field of components and systems vehicle propulsion systems, which enable executing applied, engineering and organisational tasks (P8-PAP, P9-PAP) |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
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| Znanja:<br><br>Poglobljeno strokovno teoretično in praktično znanje na področju motorjev z notranjim zgorevanje in elektrificiranih pogonskih sistemov vozil, podprto s širšo teoretično in metodološko osnovo<br><br>Spretnosti:<br><br>S1.1: Sposobnost vrednotenja različnih topologij pogonskih sistemov vozil in njihovih komponent z oziroma na zasnovo, izkoristek in trajnost komponent<br><br>S1.2: Samostojna uporaba pridobljenega znanja pri analizi in snovanju različnih topologij pogonskih sistemov vozil in njihovih komponent.<br><br>S1.3: Sposobnost snovanja okolju prijaznejših različnih topologij pogonskih sistemov vozil.<br><br>S1.4: Sposobnost nadaljnjega, samostojnega študija. | Knowledge:<br><br>Z1: In depth professional theoretical and applied knowledge in the area of internal combustion and electrified vehicle propulsion systems, supported by comprehensive theoretical and methodological basis.<br><br>Skills:<br><br>1. S1.1 Ability to evaluate different topologies of vehicle propulsion systems and their components with respect to their design, efficiency and durability of components.<br><br>2. S1.2 Independent use of knowledge for analysis and design of different topologies of vehicle propulsion systems and their components.<br><br>3. S1.3 Ability to design environmentally friendly topologies of vehicle propulsion systems |

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| | 4. S1.4 Capability of further independent self-learning in the area of piston aircraft engines. |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
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| P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. | P1: Classroom lectures with inclusion of solving selected typical and practical examples. |
| P2: Obravnava snovi po urejeni in vnaprej razloženi sistematiki. | P2: Presenting of the learning content in an orderly and pre-interpreted systematics |
| P3: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. | P3: Tutorials where theoretical knowledge of lectures is supported by computational examples. |
| P4: Laboratorijske vaje. | P4: Laboratory work. |
| P5: Uporaba študijskega gradiva v obliki (e-verzija predstavitve predavanj). | P5: Use of study materials in format (e-version of lecture presentation). |
| P8: Izdelava in predstavitev aplikativnih seminarskih nalog | P8: Design and presentation of applied seminar work |
| P10: Uporaba anket v realnem času | P10: Use of real-time surveys |
| P14: Virtualni eksperimenti | P14: Virtual Experiments |
| P15: Uporaba video vsebin kot priprava na predavanja in vaje | P15: Using video content to prepare for lectures and exercises |

| **Načini ocenjevanja:** | **Delež/ Weight** | **Assessment:** |
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| - Teoretične vsebine (predavanja) | 50,00 % | - Theory (lectures) |
| - Samostojno delo na vajah: | 50,00 % | - Practical coursework |

**Reference nosilca/Lecturer's references:**

Tomaž Katrašnik:

1. **KATRAŠNIK, Tomaž**. Impact of vehicle propulsion electrification on Well-to-Wheel CO [sub] 2 emissions of a medium duty truck. Applied energy. Aug. 2013, vol. 108, str. 236-247, ilustr. ISSN 0306-2619. DOI: 10.1016/j.apenergy.2013.03.029. [COBISS.SI-ID 12782363]
2. BANJAC, Titina, TRENC, Ferdinand, **KATRAŠNIK, Tomaž**. Energy conversion efficiency of hybrid electric heavyduty vehicles operating according to diverse drive cycles. Energy conversion and management. [Print ed.]. 2009, vol. 50, iss. 12, str. 2865-2878. ISSN 0196-8904. [COBISS.SI-ID 11100699]
3. PRAH, Ivo, TRENC, Ferdinand, **KATRAŠNIK, Tomaž**. Innovative calibration method for system level simulation models of internal combustion engines. Energies. Sep. 2016, vol. 9, iss. 9, f. 1-36, ilustr. ISSN 1996-107 http://www.mdpi.com/1996-1073/9/9/708, DOI: 10.3390/en9090708.

[COBISS.SI-ID 14830363]

4. **KATRAŠNIK, Tomaž**. Transient momentum balance - a method for improving the performance of mean - value engine plant models. Energies. Jun. 2013, vol. 6, iss. 6, str. 2892-2926, ilustr. ISSN 1996-1073. DOI: 10.3390/en6062892. [COBISS.SI-ID 12946459]
5. RODMAN OPREŠNIK, Samuel, **KATRAŠNIK, Tomaž**, SELJAK, Tine. Test report of exhaust emissions and fuel consumption of a triple-fuel spark-ignition VW Touran 2.0 Ecofuel in August 2010. Ljubljana: Fakulteta za strojništvo, 2010. 1 zv., ilustr. [COBISS.SI-ID 12100123]