UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Termodinamika
Course title:	Thermodynamics
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**
Strojništvo - razvojno raziskovalni program, prva stopnja, univerzitetni	Ni členitve (študijski program)	1. letnik	2. semester

Univerzitetna koda predmeta/University course code:	0562746
Koda učne enote na članici/UL Member course code:	2009-U

Predavanja	**Seminar**	**Vaje**	**Klinične vaje**	**Druge oblike študija**	**Samostojno delo**	**ECTS**
45		30			75	6

Nosilec predmeta/Lecturer:	Božidar Šarler, Matjaž Perpar
Vrsta predmeta/Course type:	Obvezni splošni predmet /Compulsory general course

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Izpolnjevanje pogojev za vpis v Univerzitetni študijski program I. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Academic study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
. Uvod: - cilji in namen predmeta, - uporaba termodinamike v tehniki - predstavitev učnega programa - predstavitev učnih pripomočkov, virov in načina dela, - predstavitev obveznosti študentov in napotki za uspešen študij. 2. Razvrstitev termodinamike: - termodinamika, inženirska termodinamika, klasična in moderna termodinamika, ravnotežna in neravnotežna termodinamika,	. Introduction: - objectives and purpose of the course, - application of thermodynamics in engineering, - presentation of the course program, - presentation of teaching tools, references and working methods, - presentation of student obligations and advices for successful study. 2. Classification of thermodynamics: - thermodynamics, engineering thermodynamics, classical and modern thermodynamics, equilibrium and

- nivoji popisa v termodinamiki in njena povezava z mehaniko kontinuuma in s termofluidnimi znanostmi. 3. Termodinamski koncepti: - struktura termodinamike: spremenljivke stanja, procesne spremenljivke, eksperimentalne spremenljivke. 4. Zakoni termodinamike: - Ničti zakon, - Prvi zakon, - Drugi zakon, - Tretji zakon. 5. Termodinamske spremenljivke: - termodinamske spremenjivke in definicije, ki izhajajo iz termodinamskih zakonov, - relacije za koeficiente, Maxwellove relacije, - termodinamsko ravnovesje. 6. Osnove opisa zaprtih in odprtih sistemov: - integralni ohranitveni princip, - diferencialni ohranitveni princip, - primeri. 7. Osnove opisa enosestavinskih enofaznih in večfaznih sistemov: - idealni in realni plin, - led, voda, vodna para, - Clausius-Clapeyronova enačba. 8. Osnove opisa večsestavinskih enofaznih sistemov: - delne molske količine, - mešanica idealnih plinov, - plini v stiku s kapljevinami in trdninami. 9. Osnove opisa večsestavinskih večfaznih sistemov: - Gibbsovo fazno pravilo, - fazni diagrami in njihovo računanje, - primeri. 10. Osnove opisa zapletenih sistemov: - kapilarnost, - vpliv zunanjih polj, - primeri. 11. Statistična termodinamika: - mikrostanja, makrostanja in entropija. - izračun makroskopskih količin iz mikroskopskih količin, - model kristala in model enoatomnega plina. 12. Termodinamska analiza toplotnih strojev: - Carnotov cikel, - Rankinov cikel, - Braytonov cikel, - Ottov cikel, - Dieselov cikel, - dualni cikel, - Stirlingov cikel. 13. Termodinamska analiza hladilnih naprav - stiskanje, - absorbcija, - vzvratni Braytonov cikel.	non-equilibrium thermodynamics, - levels of description in thermodynamics and its connection with continuum mechanics and thermofluid sciences. 3. Thermodynamics concepts: - structure of thermodynamics: state variables, process variables, experimental variables. 4. Thermodynamics laws: - Zeroth law, - First law, - Second law, - Third law. 5. Thermodynamics variables: - thermodynamics variables and definitions, stemming from thermodynamics laws, - relations for coefficients, Maxwell relations, - thermodynamics equilibrium. 6. Fundamentals of description of closed and open systems: - integral conservation principle, - differential conservation principle, - examples. 7. Fundamentals of description of single constituent single phase and multiphase systems: - ideal and real gas, - ice, water, water steam, - Clausius-Clapeyron equation. 8. Fundamentals of description of multi-constituent single-phase systems: - partial molar properties, - mixture of ideal gases, - gases in contact with liquids and solids. 9. Fundamentals of description of multi-constituent multi-phase systems: - Gibbs phase rule, - phase diagrams and their calculation, - examples. 10. Fundamentals of description of complicated systems: - capillarity, - influence of external fields, - examples. 11. Statistical thermodynamics: - microstates, macrostates and entropy, - calculation of macroscopic quantities from microscopic quantities, - model of crystal and model of monoatomic gas. 12. Thermodynamics analysis of heat engines: - Carnot cycle, - Rankin cycle, - Brayton cycle, - Otto cycle, - Diesel cycle, - dual cycle,

14. Osnove opisa atmosferskega zraka: - psihrometrija, metode za določanje vlažnosti, pogoji ugodja, - hlajenje in sušenje zraka, - segrevanje in vlaženje zraka - hladilni stolpi. 15. Zgorevanje: - kemijske reakcije, opis zgorevanja, - določanje reaktantov iz produktov, - toplota in entropija pri zgorevanju.	- Stirling cycle. 13. Thermodynamics analysis of cooling devices: - compression, - absorbtion, - inverse Brayton cycle. 14. Fundamentals of description of atmospheric air: - psychometry, methods for determination of humidity, conditions of comfort, - cooling and heating of air, - heating and humidifying air, - cooling towers. 15. Combustion: - chemical reactions, description of combustion, - determination of reactants from the products, - heat and entropy in combustion.

Temeljna literatura in viri/Readings:

1. .R. Reisel, Principles of Engineering Thermodynamics, Cengage Learning, Boston, 2016.
2. J.A. Cengel, M.A. Boles, Therodynamics: An Engineering Approach, Ms-Graw Hill, New York, 2011.
3. R. DeHoff, Thermodynamics in Materials Science, Second Edition CRC Press, Boca Raton, 2006.

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Predstaviti osnove in uporabo termodinamike. 2. Predstaviti strukturo termodinamike in teoretični ter metodološki pristop k reševanju različnih termodinamskih sistemov. 3. Predstaviti praktično uporabo termodinamike na številnih inženirskih primerih. 4. Navdušiti študente za nadaljni, bolj poglobljeni študij predstavljenih osnov. Kompetence: 1. P1-RRP, P2-RRP: Biti sposoben razpoznave različnih termodinamskih sistemov, njihovega teoretičnege opisa in metodologije obravnave. 2. P4-RRP: Biti sposoben reševanja širokega spektra termodinamskih problemov. 3. P6-RRP: Biti sposoben termodinamske optimizacije inženirskih sistemov glede na učinkovitost, kvaliteto in vpliva na okolje.	Objectives: 1. To present the fundamentals and application of thermodynamics. 2. To present the structure of thermodynamics and theoretical and methodological approach for solving different thermodynamic systems. 3. Demonstrate the practical use of thermodynamics on various engineering cases. 4. To inspire the students for further, more in-depth study of the presented fundamentals. Competences: 1. P1-RRP, P2-RRP: Being able to identify different thermodynamic systems, their theoretical description and approach methodology. 2. P4-RRP: Being able to solve a wide range of themodynamic problems. 3. P6-RRP: Being able to make a thermodynamic optimization of engineering systems in terms of efficiency, quality and environmental impact.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Poglobljeno strokovno teoretično in praktično znanje termodinamike, podprto s primerno široko teoretično in metodološko osnovo.	Knowledge: Z1: Thorough professional theoretical and practical knowledge of thermodynamics that is supported with a broad theoretical and methodological basis.

Spretnosti: S1.1 Hitra prilagoditev reševanju različnih termodinamskih sistemov. S1.2 Samostojna uporaba znanja pri snovanju inženirskih termodinamskih sistemov. - Reševanje problemov glede na učinkovitost, kvaliteto in vpliv na okolje. - Biti sposoben nadaljnjega, poglobljenega samostojnega študija.	Skills: S1.1 Rapid adaptation to solving of various thermodynamic systems. S1.2 Independent use of knowledge in the design of thermodynamic systems. - Solving problems in terms of efficiency, quality and environmental impact. - To be able to further independently in-depth study.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1: Avditorni način predavanja. 2. P14: Občasna uporaba računalniške animacije. 3. P5: Uporaba študijskega gradiva v obliki skripta predavanj. 4. P14: Virtualni eksperimenti. 5. P15: Uporaba video vsebin kot priprava na predavanja in vaje. 6. P3: Avditorialne vaje - teoretično znanje podkrepljeno s praktičnimi računskimi primeri. 7. P5: Uporaba študijskega gradiva v obliki učbenika za vaje. 8. P4: Laboratorijske vaje: določanje specifične toplote trdne snovi, fazne spremembe, določanje krivulje kapljevina-plin za vodo v P-T diagramu, določanje termodinamskih stanj pri ekspanziji in kompresiji idealnega plina.	. P1: Auditorial lectures. 2. P14: Occasional use of computer animation. 3. P5: Use of study materials in the form of a lecture script. 4. P14: Virtual experiments. 5. P15: Using video contents as a preparation for lectures and exercises. 6. P3: Auditorial exercises - theroetical knowledge supported by calculations of practical examples. 7. P5: Use of study materials in the form of an excercise textbook. 8. P4: Laboratory work: determination of the specific heat of the solid, phase changes, determination of the liquid-gas curve for water in P-T diagram, determination of the thermodynamic states at the expansion and compression of the ideal gas.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Pisni izpit	50,00 %	Written exam
Naloge	50,00 %	Exercises

Reference nosilca/Lecturer's references:

Božidar Šarler

1. KOVAČIČ, Miha, **ŠARLER, Božidar**. Genetic programming prediction of the natural gas consumption in a steel plant. Energy. [Print ed.]. 2014, vol. 66, str. 273-284. ISSN 0360-5442. DOI: 10.1016/j.energy.2014.02.00 [COBISS.SI-ID 3219707]
2. KOVAČIČ, Miha, STOPAR, Klemen, VERTNIK, Robert, **ŠARLER, Božidar**. Comprehensive electric arc furnace electric energy consumption modeling: a pilot study. Energies. Jun. 2019, vol. 12, iss. 11, f. 1-13, ilustr. ISSN 1996-1073. https://www.mdpi.com/1996-1073/12/11/2142, DOI: 10.3390/en1211214 [COBISS.SI-ID 16647451]
3. HANOGLU, Umut, **ŠARLER, Božidar**. Multi-pass hot-rolling simulation using a meshless method. Computers & Structures. [Print ed.]. Jan. 2018, vol. 194, str. 1-14, ilustr. ISSN 0045-7949. http://ac.els-cdn.com/S004579491730038X/1-s2.0-S004579491730038X-main.pdf?_tid=d90e0950-9397-11e7-b016-00000aab0f26&acdnat=1504766785_f7050a8813a3d32e98f6a93afb8e7f30, DOI:

10.1016/j.compstruc.2017.08.012. [COBISS.SI-ID 15624731]

4. VUŠANOVIĆ, Igor, **ŠARLER, Božidar**, KRANE, Matthew J. M. Microsegregation during the solidification of an Al-Mg-Si alloy in the presence of back diffusion and macrosegregation. Materials Science & Engineering.A, Structural materials: Properties, Microstructure and Processing. [Print ed.]. 2005, vol. 413\414, str. 217-222. ISSN 0921-5093. [COBISS.SI-ID 450555]
5. MUKHOPADHYAY, Ananya, **ŠARLER, Božidar**, POLO, Andrea, OMETTO, Marco. Integration of automation solutions of casting and rolling for better control of product quality. V: AISTech 2011: proceedings of the Iron & Steel Technology Conference, May 2-5, 2011, Indianapolis, Indiana, USA. Warrendale: Association for Iron and Steel Technology, cop. 2011. Vol. 2, str. 1007-1020. ISBN 978-1-935117-18-6, ISBN 978-1-935117-19-3. [COBISS.SI-ID 2423547]

Matjaž Perpar

1. **PERPAR, Matjaž**, REK, Zlatko. *Soil temperature gradient as a useful tool for small water leakage detection from district heating pipes in buried channels*. Energy, ISSN 0360-5442, 2020, vol. 201, str. 1-13, ilustr. https://www.sciencedirect.com/science/article/pii/S036054422030791X?via%3Dihub%20, doi: 10.1016/j.energy.2020.117684. [COBISS.SI-ID 17172763].
2. **PERPAR, Matjaž**, REK, Zlatko, BAJRIĆ, Suvad, ŽUN, Iztok. *Soil thermal conductivity prediction for district heating pre-insulated pipeline in operation*. Energy, ISSN 0360-5442, 2012, vol. 44, str. 197-210, ilustr. [COBISS.SI-ID 12406555].
3. ŽUN, Iztok, **PERPAR, Matjaž**, GREGORC, Jurij, HAYASHI, Kosuke, TOMIYAMA, Akio. *Mixing of thermally stratified water layer by a free rising wobbling air bubble*. Chemical Engineering Science, ISSN 0009-2509. [Print ed.], 2012, vol. 72, iss. [4], str. 155-171, ilustr., doi: 10.1016/j.ces.2011.12.024. [COBISS.SI-ID 12220187].
4. **PERPAR, Matjaž**, POLUTNIK, Erazem, PEČAR, Marko, ŽUN, Iztok. *Bubbly structures in a cavitating slot orifice*. Experimental thermal and fluid science, ISSN 0894-1777. [Print ed.], Feb. 2014, vol. 53, str. 57-69, ilustr., doi: 10.1016/j.expthermflusci.2013.11.003. [COBISS.SI-ID 13255963].
5. **PERPAR, Matjaž**, LUŠTRIK, Matevž, DREU, Rok, SRČIČ, Stanko, ŽUN, Iztok. *Estimating coating quality parameters on the basis of pressure drop measurements in a Wurster draft tube*. Powder technology, ISSN 0032-5910. [Print ed.], Sept. 2013, vol. 246, str. 41-50, ilustr. https://www.sciencedirect.com/science/article/pii/S0032591013003513, doi: 10.1016/j.powtec.2013.05.005. [COBISS.SI-ID 3453553]