UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	TERMODINAMIKA
Course title:	THERMODYNAMICS

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

Univerzitetna koda predmeta/University course code:	2021

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
60		30			110	8

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

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Opravljanje študijskih obveznosti je opredeljeno v Pravilniku o preverjanju in ocenjevanju znanja študenta na UL FS. Za pozitivno in uspešno opravljanje študijskih obveznosti ter vključevanje v študijsko delo se priporoča redno obiskovanje predavanj, reševanje dodatnih domačih bolj zahtevnih nalog, študij dopolnilnih učnih pripomočkov iz teorije, ki so namenjeni za poglobljen študij in ustrezna predpriprava pred izvajanjem laboratorijskih vaj ter izkazana aktivnost (vsaj 80% prisotnost) na vajah	The execution of study obligations is defined in the Rules on testing and grading the knowledge of students at UL FS. In order to pass and successfully execute the study obligations and participate in study work, the students are advised to regularly attend the lectures, do additional homework assignments of greater complexity, study additional theoretical teaching aids for an in-depth comprehension, as well as to prepare adequately for laboratory exercises and actively participate at exercises (at least 80% presence).

Vsebina:	**Content (Syllabus outline):**
• **SISTEM** Kompleksni sistemi, razgradnja, termodinamski {P,Q} sistem Krajevna skala: element, stanje; Časovna skala: proces. Strukturna slika, princip povratne zanke; ožji sistem, širši sistem, ožja okolica, širša okolica. • **LASTNOSTI ČISTIH SNOVI** Agregatna stanja: trdnina, kapljevina, plin (para) Trdnine: temperaturno raztezanje, toplotna napetost Kapljevine: temperaturno raztezanje, anomalija vode Plini: PVT sistem, termična enačba stanja; realni plini, fazne spremembe.	• **System** Complex systems, breakdown, thermodynamic {P, Q} system. Local scale: element, state; Time scale: process. Structural model, principle of feedback loop; narrower system, wider system, narrower surroundings, wider surroundings. • **Properties of pure materials** States of matter: solids, liquids, gas (steam). Solids: temperature expansion, thermal stress. Liquids: temperature expansion, anomalies of water. Gases: PVT system, thermal equation of state; real gases, phase transitions.

• **PRVI GLAVNI ZAKON TERMODINAMIKE** Nakopičene energije, prehodne energije. Delo, tehnično delo, toplota. Kalorična enačba stanja, toplotna kapaciteta. Preobrazbe idealnih plinov • **DRUGI GLAVNI ZAKON TERMODINAMIKE** Nepovračljivost. Entropija. Termodinamska razmerja; Helmholtzova funkcija, Gibbsova funkcija, Maxwellova termodinamska razmerja. Clapeyronova enačba, Joule-Thompsonov koeficient. Eksergija in anergija. Termodinamske bilance • **SKLOPLJENI PROCESI** Strukturna analiza, ničti zakon, prvi glavni zakon, drugi glavni zakon: Delovni cikel in povratna zanka, Parni stroj in Rankinov cikel. Izboljšave parnega procesa. Plinski procesi. Motorji z notranjim zgorevanjem. Hladilni in grelni procesi; Lastnosti hladilnih snovi. Parni hladilni procesi. Toplotna črpalka Obdelovalni procesi. Transportni procesi	• **First law of thermodynamics** Accumulated energies, transient energies. Work, technical work, heat. Caloric equation of state, heat capacity. Ideal gas laws. • **Second law of thermodynamics** Irreversibility. Entropy. Thermodynamic relations; Helmholtz function, Gibbs function, Maxwell's thermodynamic relations. Clapeyron relation, Joule-Thomson coefficient. Exergy and anergy. Thermodynamic balances. • **Coupled processes** Structural analysis, zeroth law, first law, second law: Power cycle and feedback loop Steam engine and Rankine cycle. Improvements to the steam process. Gas processes. Internal combustion engines. Cooling and heating processes; properties of coolants. Steam cooling processes. Heat pump Transformation processes. Transport processes.

Temeljna literatura in viri/Readings:

[1] Çengel, Y.A., Boles, M.A., **Thermodynamics: An Engineering Approach**, Fifth Edition, McGraw-Hill 2006. - Izbrana poglavja 1,2,3,4,6,7,8,9,10,11,12.
[2] Oprešnik, M., **Termodinamika**, četrta izdaja, Fakulteta za strojništvo, 1992. - vsa poglavja od 1 do 9.
[3] Žun, I., Zapiski predavanj za predlagani predmet v pisni obliki (handouts).

Cilji in kompetence:	**Objectives and competences:**
Cilji: Temeljni cilji učnega predmeta so seznaniti študente z lastnostmi snovi s posebnim poudarkom na temperaturi ter s prvimi principi termodinamike, ki so zapisani z ničtim, prvim in drugim glavnim zakonom termodinamike. Pri tem je dan poseben poudarek na nepovračljivosti procesov. **Kompetence:** Študent bo pridobil sposobnosti jasnega in logičnega razgrajevanja skal kompleksnega tehniškega sistema, ki vodi k rapoznavanju osnovnih termodinamskih principov. Pri tem bo sposoben kritične ocene energijskih in eksergijskih izgub procesov z vidika trajnostnega razvoja.	**Goals:** The fundamental goal of this study course is to acquaint the students with material properties, placing a special emphasis on the temperature and the basic principles of thermodynamics, formalised with the zeroth, first and second law of thermodynamics. A special emphasis is placed on the irreversibility of processes. **Competences:** The students will earn the ability of a clear and logical breakdown of the scales of a complex technical system, leading to the recognition of the basic principles of thermodynamics. They will be able to critically evaluate the energy and exergy losses in processes from the viewpoint of sustainable development.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Po uspešno dokončanem opravljanju študijskih obveznosti bo študent sposoben: • razumeti snovske lastnosti materialov, s posebnim poudarkom na plinih in parah • znal določiti spremembe fizikalnih lastnosti vključno s spremembami agregatnega stanja • znal določiti potrebno količino dovedene ali odvedene toplote za dosego zaželjenih učinkov pri delovnih, grelnih in hladilnih procesih. • znal ovrednotiti kvaliteto procesov z energijskega vidika	***Knowledge and understanding*** Upon the successful completion of study obligations, the students will be capable to: • understand the material properties, with a special emphasis on gases and steams, • determine the changes of physical properties, including the changes of state of matter, • determine the necessary quantity of input or output heat necessary to achieve the desired effects of work, heating and cooling processes, • assess the quality of processes from the energy point of view.

Absolvent predmeta termodinamike bo moral biti sposoben oceniti pomen trajnostnega razvoja v tehniki. ***Uporaba*** Pridobljeno znanje pri predmetu bo študentu posebej koristilo za reševanje problemov vezanih na temperaturne spremembe, kot n. pr. uporabo plinov oz. par v tehnične namene. Uporaba bo možna v celi vrsti aplikacij vezanih na toploto ali pa pridobivanje dela. Predvsem pa se pričakuje sposobnost razpoznavanja nekaterih ontolških značilnosti kompleksnih sistemov z vidika nepovračljivosti procesov, kar je ključen problem trajnostnega razvoja v tehniki. ***Refleksija*** Pridobljeno teoretično znanje pri predmetu in izkušnje pridobljene pri računskih vajah in eksperimentiranju v laboratorijskem okolju, bodo uporabne za različne razvojno-raziskovalne in praktične namene na področju energetike, procesnega strojništva, proizvodnega strojništva in pri snovanju novih konstrukcij. ***Prenosljive spretnosti – niso vezane le na en predmet*** Uporaba sodobne strokovne literature in praktično delo z sodobno merilno in programsko opremo v urejenem in mednarodno uveljavljenem laboratorijskem okolju.	A student who completes the thermodynamics course will have to be able to evaluate the importance of sustainable development in engineering. ***Usage*** The knowledge acquired in this course will benefit the students especially in solving the problems related to temperature changes, such as e.g. the use of gases and steams for technical purposes. The knowledge can be used in numerous applications related to heat or production of work. Above all, the students are expected to recognise some ontological characteristics of complex systems from the viewpoint of irreversibility of processes, as the key problem of sustainable development in engineering. ***Reflexion*** The theoretical knowledge acquired in the course and the experience gained through computational exercises and experimenting in the laboratory environment will be useful for different research and development and practical purposes in the field of power engineering, process engineering, production engineering, as well as for designing new structures. ***Transferable skills – related to more than one course*** The use of modern professional literature and practical work using modern measuring and software equipment in an orderly and internationally recognised laboratory environment.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja z reševanjem posebej izbranih vzorčnih teoretičnih in praktično uporabnih primerov. Metode poučevanja bodo avditorne z uporabo različnih sodobnih tehnik, kot so n. pr. računalniške animacije in sprotno učenje s svetovnega spleta.	Lectures involving solving of specially selected examples of theoretical and practically applicable cases. The teaching will be done in the lecture room and using various modern techniques, such as computer animations and continuous learning from the world wide web.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Splošna pravila: Študijska uspešnost študenta pri usvajanju kompetenc učnega predmeta se ugotavlja sprotno na način, ki odraža specifiko predmetnih vsebin (laboratorijske vaje, domače naloge, projektne seminarske naloge), in periodično s preverjanjem posameznih delov snovi (kolokviji, testi). Zaključno oceno pri predmetu študent pridobi z izpitom, ki je pisni in/ali ustni, pri čemer k oceni prispeva tudi ugotovljena uspešnost pri sprotnem in periodičnem preverjanju. Posebna pravila: Podrobna pravila o delu in načinu merjenja študijske uspešnosti študenta pri predmetu z opredeljenimi deleži so podane na spletnem naslovu: http://lab.fs.uni-lj.si/lfdt/pdf/termodinamika-ir.pdf		General rules: The students' performance in mastering the study course competences is determined continuously in a way that reflects the specifics of course topics (laboratory exercises, homework assignments, project seminar papers), and periodically by testing the individual parts of subject matter (colloquia, tests). The student obtains a final grade for the course by means of a written and/or oral exam. The assessment of his/her performance in continuous and periodic testing is also accounted for in the final grade. Special rules: Detailed rules on work and method of the student's study performance assessment for the course with defined weights are available at the following web address: http://lab.fs.uni-lj.si/lfdt/pdf/termodinamika-ir.pdf

Reference nosilca/Lecturer's references:

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ŠARLER, Božidar, VERTNIK, Robert. Meshfree local radial basis function collocation method for diffusion problems. Computers & Mathematics with Applications, ISSN 0898-1221. [Print ed.], 2006, vol. 51, str. 1269-1282.
KOVAČEVIĆ, Igor, ŠARLER, Božidar. Solution of a phase-field model for dissolution of primary particles in binary aluminum alloys by an r-adaptive mesh-free method. Materials Science & Engineering. A, Structural materials: Properties, Microstructure and Processing, ISSN 0921-5093. [Print ed.], 2005, vol. 413\414, str. 423-428.
KOVAČIČ, Miha, ŠARLER, Božidar. Genetic programming prediction of the natural gas consumption in a steel plant. Energy, ISSN 0360-5442. [Print ed.], 2014, vol. 66, str. 273-284, doi: 10.1016/j.energy.2014.02.001.
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