

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Prenos toplote in snovi
Course title:	HEAT AND MASS TRANSFER
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Mehatronika (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Energetsko strojništvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Procesno strojništvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje strojev in naprav (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje industrijskih sistemov (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Proizvodne tehnologije (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Industrijsko inženirstvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Prometni pilot letala/helikopterja (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Snovanje in vzdrževanje letal (smer)	2. letnik	1. semester

Univerzitetna koda predmeta/University course code: 0562716

Koda učne enote na članici/UL Member course code: 3019-V

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
30		30			40	4

Nosilec predmeta/Lecturer: Andrej Kitanovski

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:

Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.

Prerequisites:

Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.

Vsebina:

1. Pomen in vloga prenosa toplote in snovi:
 - Predstavitev osnovnih mehanizmov prenosa toplote in snovi (prevod toplote, difuzija snovi, konvektivni prenos snovi ali toplote, sevanje toplote, sočasni prenos toplote in snovi);
 - Pregled toplotnih lastnosti snovi;
 - Primeri v praksi.
2. Prevod toplote 1:
 - Fourierov zakon;
 - Enodimenzijski stacionarni prevod toplote (ravna stena, večplastna ravna stena, ukrivljena stena, večplastna ukrivljena stena);
 - Upor toplote in analogija električnih tokokrogov;
 - Termična difuzivnost in njen pomen;
 - Praktični primeri.
3. Prevod toplote 2:
 - Dvodimenzijski stacionarni prevod toplote (enostavni primeri reševanja, vključno z uvedbo enostavnih numeričnih metod);
 - Praktični primeri.
4. Prevod toplote 3:
 - Nestacionarni prevod toplote z enostavnimi analitičnimi primeri reševanja;
 - Nestacionarni prevod toplote z enostavnimi numeričnimi metodami ali programskimi orodji;
 - Praktični primeri.
5. Difuzija snovi 1:
 - Fickov zakon in analogija prevoda toplote in difuzije snovi;
 - Stacionarna difuzija snovi (enodimenzijska difuzija, ravna stena, večplastna ravna stena, ukrivljena stena, večplastna ukrivljena stena);
 - Upor pri difuziji snovi in nadomestna difuzijska upornost;
 - Praktični primeri;
6. Difuzija snovi 2:
 - Ekvimolarna difuzija snovi;
 - Enostranska difuzija snovi;
 - Praktični primeri.
7. Difuzija snovi 3:
 - Nestacionarna difuzija snovi z enostavnimi analitičnimi primeri reševanja;
 - Nestacionarna difuzija snovi z enostavnimi numeričnimi metodami ali programskimi orodji;
 - Praktični primeri .

Content (Syllabus outline):

1. Meaning and role of heat and mass transfer:
 - Introduction of basic mechanisms (heat conduction, mass diffusion, convective heat and mass transfer, heat radiation, simultaneous heat and mass transfer);
 - Thermal properties of materials;
 - Examples from practice.
2. Heat conduction 1:
 - Fourier law;
 - One-dimensional steady state conduction (flat wall, composite flat wall, circular structures, composite circular structures);
 - Thermal resistance and analogy with electrical circuits;
 - Thermal diffusivity and its meaning;
 - Practical examples.
3. Heat conduction 2:
 - Two-dimensional steady state thermal conduction (simple examples, including simple numerical methods);
 - Practical examples.
4. Heat conduction 3:
 - Transient heat conduction with simple analytical examples;
 - Transient heat conduction with simple numerical methods or program tools;
 - Practical examples.
5. Mass diffusion 1:
 - Fick's law and analogy between heat and mass transfer;
 - Steady state mass diffusion (one-dimensional diffusion, flat wall, composite flat wall, circular objects, circular composite objects);
 - Mass transfer resistance and analogy with electrical circuits;
 - Practical examples;
6. Mass diffusion 2:
 - Equimolar mass diffusion;
 - One-direction mass diffusion;
 - Practical examples.
7. Mass diffusion 3:
 - Transient mass diffusion with simple analytical examples;
 - Transient mass diffusion with simple numerical methods and program tools;
 - Practical examples .
8. Convective heat transfer 1:

<p>8. Konvektivni prenos toplote 1:</p> <ul style="list-style-type: none"> - Uvod v konvektivni prenos toplote skozi praktične primere; - Newtonov zakon hlajenja (prestop toplote); - Pomen in izračun hitrostne in termične mejne plasti; - Brezdimenzijska števila in njihove relacije. <p>9. Konvektivni prenos toplote 2:</p> <ul style="list-style-type: none"> - Tok preko obtekane plošče z različnimi primeri; - Obtekana telesa; - Notranji tokovi (nerazvit tok, polno-razvit tok) z različnimi primeri; - Naravna konvekcija. <p>10. Konvektivni prenos snovi 1:</p> <ul style="list-style-type: none"> - Uvod v konvektivni prenos snovi skozi praktične primere; - Pomen in izračun hitrostne in mejne plasti koncentracij; - Meje med koncentracijami (Henryev in Raultov zakon); - Brezdimenzijska števila in njihove relacije. <p>11. Konvektivni prenos snovi 2:</p> <ul style="list-style-type: none"> - Tok preko obtekane plošče z različnimi primeri; - Obtekana telesa; - Notranji tokovi (nerazvit tok, polno-razvit tok) z različnimi primeri. <p>12. Sevanje:</p> <ul style="list-style-type: none"> - Wienov zakon, Stefan-Boltzmanov zakon, Kirchoffov zakon; - Absorpcija, refleksija in transmisija; - Faktor medsebojnega videnja; - Preračun sevanja toplote (v okolico, med dvema telesoma); - Praktični primeri. <p>13. Prenosniki toplote 1:</p> <ul style="list-style-type: none"> - Delitev prenosnikov toplote glede na vrsto tekočin, geometrijske značilnosti; - Učinkovitost in izkoristek, pomen NTU; - Dimenzioniranje prenosnikov toplote (srednja logaritemska temperaturna razlika in epsilon-NTU metoda). <p>14. Prenosniki toplote 2:</p> <ul style="list-style-type: none"> - Razširjene površine in preračun; - Dimenzioniranje prenosnikov toplote s križnim tokom in proti-tokom; - Praktični primeri. <p>15. Sočasni prenos toplote in snovi:</p> <ul style="list-style-type: none"> - Relacije med prenosom toplote in prenosom snovi, brezdimenzijska števila; - Praktični primeri: izhlapevanje/kondenzacija; - Praktični primeri: sublimacija/desublimacija. 	<ul style="list-style-type: none"> - Introduction to convective heat transfer with practical examples; - Newton's law of cooling; - The meaning and calculation of velocity and thermal boundary layer; - Non-dimensional numbers and their relations. <p>9. Convective heat transfer 2:</p> <ul style="list-style-type: none"> - Flow over heated plate with different examples; - Flow over bodies; - Internal flow (developing flow, fully developed flow) with different examples; - Natural convection. <p>10. Convective mass transfer 1:</p> <ul style="list-style-type: none"> - Introduction to convective mass transfer with practical examples; - The meaning and calculation of velocity and concentration boundary layer; - Boundaries between concentrations (Henry's and Rault's law); - Non-dimensional numbers and their relations. <p>11. Convective mass transfer 2:</p> <ul style="list-style-type: none"> - Flow over plate with different examples; - Flow over bodies; - Internal flow (developing flow, fully-developed flow) with different examples. <p>12. Heat radiation:</p> <ul style="list-style-type: none"> - Wien's law, Stefan-Boltzman's law, Kirchoff's law; - Absorption, reflection and transmissivity; - The view factor; - Radiative heat transfer (into environment, between two bodies); - Practical examples. <p>13. Heat exchangers 1:</p> <ul style="list-style-type: none"> - Types of heat exchangers (fluid, geometry); - Effectiveness and efficiency, the meaning of NTU; - Dimensioning of heat exchangers (log mean temperature difference and epsilon-NTU method). <p>14. Heat exchanger 2:</p> <ul style="list-style-type: none"> - Extended surfaces and calculation; - Dimensioning of cross-flow and counter flow heat exchangers; - Practical examples. <p>15. Simultaneous heat and mass transfer:</p> <ul style="list-style-type: none"> - Relations between heat and mass transfer, dimensionless numbers;; - Practical examples: evaporation/condensation; - Practical examples: sublimation/desublimation.
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Temeljna literatura in viri/Readings:

1. Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt Fundamentals of Heat and Mass Transfer, 8th Edition, 2018
2. Baehr, Hans Dieter, Stephan, Karl, Heat and Mass Transfer, Springer, 2011
3. VDI Heat Atlas, Springer, 2010

Cilji in kompetence:

Cilji:

Glavni cilj predmeta je posredovanje znanja študentom za razumevanje, reševanje, analizo in izboljšave praktičnih problemov povezanih s prenosom toplote in snovi. S tem predmet dosega sledeče pod-cilje:

1. Razumevanje osnovnih principov prenosa toplote in snovi
2. Sposobnost analize različnih problemov s področja prenosa toplote in snovi
3. Sposobnost implementacije znanja ter optimizacije procesov prenosa toplote in snovi v praktičnih primerih

Kompetence

1. S1-PAP, P1-PAP: Razumevanje principov prenosa toplote in snovi ter njihovih procesov v različnih domenah strojništva.
2. S5-PAP, P3-PAP: Sposobnost implementacije znanja pri analizi različnih primerov s področja prenosa toplote in snovi.
3. S13-PAP, P8-PAP: Sposobnost implementacije znanja pri izboljšavah ali razvoju procesov ter izdelkov, ki pri svojem delovanju temeljijo na prenosu toplote in snovi.

Objectives and competences:

Objectives:

The main objective of the subject is to provide student with knowledge and skills for understanding, solving problems, analysis and improvements of practical cases in heat and mass transfer. This is supported by the following sub-objectives:

1. Understanding of basic heat and mass principles
2. Ability for analysis of different problems from heat and mass transfer
3. Ability for implementation of knowledge and optimization of heat and mass transfer processes in practical examples.

Competences

1. S1-PAP, P1-PAP: Understanding of principles of heat and mass transfer and their processes in different domains of mechanical engineering.
2. S5-PAP, P3-PAP: Ability for implementation of knowledge for analysis of different examples from heat and mass transfer.
3. S13-PAP, P8-PAP: Ability for implementation of knowledge and skills for improvements or developments of processes and products, whose operation depends on heat and mass transfer.

Predvideni študijski rezultati:

Znanja:

Z1: Poglobljeno strokovno teoretično in praktično znanje s področja prenosa toplote in snovi, podprto s širšo teoretično in metodološko osnovo, ki omogoča implementacijo znanja v praksi.

Spretnosti:

S1.2: Obvladovanje analiz, načrtovanja in implementacije procesov prenosa toplote in snovi v industrijskih procesih, napravah ali sistemih.

S1.3: Sposobnost identifikacije in izboljšav procesov prenosa toplote in snovi v različnih industrijskih okoljih, napravah, ali sistemih.

Intended learning outcomes:

Knowledge:

Z1: In-depth professional theoretical and practical knowledge from the field of heat and mass transfer, supported with broader theoretical and methodological basis, which enables implementation of knowledge in practice.

Skills:

S1.2: Mastering analysis, planning and implementation of heat and mass processes in industry, different devices and systems.

S1.3: Ability for identification and improvement of heat and mass processes in different industrial environments, devices or systems.

Metode poučevanja in učenja:

P1: Avditorna predavanja z reševanjem izbranih - za

Learning and teaching methods:

P1: Classroom lectures focused on solving topic specific

področje značilnih - teoretičnih in praktično uporabnih primerov.	theoretical and practical examples.
P3: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.	P3: Classroom tutorials where theoretical knowledge is supported by computational examples.
P4: Laboratorijske vaje z namenskimi didaktičnimi pripomočki (demonstracijski pripomoček stacionarnega in nestacionarnega prevoda toplote, demonstracijski pripomoček za toplotno sevanje, naprava za konvektivni prenos toplote na ravnih in razširjenih površinah, naprava za demonstracijo in meritve pri procesu izhlapevanja, pripomoček za demonstracijo enostranske difuzije snovi, prenosnik toplote cev-v-cevi).	P4: Laboratory exercises with dedicated didactic means (demonstration device for steady and transient heat transfer, demonstration device for radiative heat transfer, demonstration device for convective heat transfer on flat and extended surfaces, demonstratio device for evaporation process, demonstration device for one-directional mass diffusion, tube-in-tube heat exchanger).
P5: Uporaba študijskega gradiva v obliki (skripta z vajami, e-verzija predstavitve predavanj).	P5: Study material in the form of (script with excercizes, e-version of lectures).
P8: Izdelava in predstavitev aplikativnih seminarских nalog s področja prenosa toplote in snovi.	P8: Application-oriented seminary work and its presentation from the field of heat and mass transfer.
P12: Individualizirane domače naloge v spletni učilnici.	P12: Individualized homework in an online classroom.
P14: Virtualni eksperimenti.	P14: Virtual experiments.
P15: Uporaba video vsebin kot priprava na predavanja in vaje.	P15: The use of video contents for lectures and excercizes.

Načini ocenjevanja:	Delež/Weight	Assessment:
Teoretične vsebine (predavanja, računske naloge).	50,00 %	Theory (from lectures and excercize problems).
Samostojno delo na vajah.	25,00 %	Individual work at excercizes.
Praktični seminar.	25,00 %	Practical seminary work.

Reference nosilca/Lecturer's references:

Andrej Kitanovski:

- ŠARLAH, Alen, **KITANOVSKI, Andrej**, POREDOŠ, Alojz, EGOLF, Peter W., SARI, Osmann, GENDRE, F., BESSON, Ch. Static and rotating active magnetic regenerators with porous heat exchangers for magnetic cooling. International journal of refrigeration, ISSN 0140-7007. [Print ed.], 2006, letn. 29, št. 8, str. 1332-1339. <http://dx.doi.org/10.1016/j.ijrefrig.2006.07.013>. [COBISS.SI-ID 9805595], [JCR, SNIP, WoS]
- EGOLF, Peter W., **KITANOVSKI, Andrej**, ATA-CAESAR, D., VUARNOZ, Didier. Cold storage with ice slurries. International journal of energy research, ISSN 0363-907X, 2008, vol. 32, iss. 3, str. 187-203, doi: 10.1002/er.1340. [COBISS.SI-ID 11241755], [JCR, SNIP, WoS]
- TUŠEK, Jaka, **KITANOVSKI, Andrej**, ZUPAN, Samo, PREBIL, Ivan, POREDOŠ, Alojz. A comprehensive experimental analysis of gadolinium active magnetic regenerators. Applied thermal engineering, ISSN 1359-4311. [Print ed.], 2013, vol. 53, iss. 1, str. 57-66, ilustr., doi: 10.1016/j.applthermaleng.20101.015. [COBISS.SI-ID 12647707], [JCR, SNIP, WoS]
- POREDOŠ, Primož, **KITANOVSKI, Andrej**, ŠUKLJE, Tomaž, ARKAR, Ciril, MEDVED, Sašo. Design and experimental-based thermal characterization of heat exchangers made of wavy tubes. V: Proceedings of the 28th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, 29th June - 3rd July 2015, Pau, France : ECOS 2015, 2015, [COBISS.SI-ID 14114331], [Scopus]
- PETELIN, Nada, VIDRIH, Boris, **KITANOVSKI, Andrej**. Heat recovery systems for a dishwasher: concepts and analysis : final report. Ljubljana: Faculty of mechanical engineering, Laboratory for refrigeration and district

energy, 2018. 54 f., ilustr. [COBISS.SI-ID 16103195]