

# PROCESNA TEHNIKA

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Procesna tehnika
<b>Course title:</b>	Process engineering
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Procesno strojništvo (smer)	2. letnik	1. semester	obvezni

<b>Univerzitetna koda predmeta/University course code:</b>	0566926
<b>Koda učne enote na članici/UL Member course code:</b>	6021-M

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			65	5

<b>Nosilec predmeta/Lecturer:</b>	Iztok Golobič, Matevž Zupančič
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<b>Izvajalci predavanj:</b>	
<b>Izvajalci seminarjev:</b>	
<b>Izvajalci vaj:</b>	
<b>Izvajalci kliničnih vaj:</b>	
<b>Izvajalci drugih oblik:</b>	
<b>Izvajalci praktičnega usposabljanja:</b>	

<b>Vrsta predmeta/Course</b>	Obvezni strokovni predmet na smeri Procesno
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**type:**

strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Process Engineering, which is an elective specialised course in other fields of study.

**Jeziki/Languages:**

Predavanja/Lectures:	Slovenščina
Vaje/Tutorial:	Slovenščina

**Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:****Prerequisites:**

Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program.

Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

**Vsebina:****Content (Syllabus outline):**

1. Uvod v procesno tehniko
  - Kronološki pregled, procesno inženirstvo in trajnostni razvoj;
  - Razvojne smeri na področju procesnih tehnologij inženirstva, zdravja, prehrane in zmanjšanja okoljskega onesnaževanja.
2. Uvod v termično procesno inženirstvo
  - Separacijski termični procesi;
  - Mehanizmi ločevanja snovi in parametri izbora procesa.
3. Upajanje in destilacija
  - Uparjanje, uparjalniki;
  - Destilacija, destilacija binarnih in večkomponentnih zmesi.
4. Rektifikacija
  - Rektifikacija, prenos toplote in snovi v pojačevalnem in odgonskem delu rektifikacijske kolone;
  - Rektifikacijski procesi v McCabe Thielejevem diagramu.
5. Načrtovanje rektifikacijske naprave
  - Entalpijska analiza rektifikacijskega procesa;
  - Modeliranje dinamike rektifikacijskega procesa.
6. Absorpcija, adsorpcija, ekstrakcija in kristalizacija
  - Absorpcija, binarna in

1. Introduction to process engineering
  - Chronological overview, the role process engineering in sustainable development;
  - R&D directions in process engineering fields including health, food and environmental pollution control.
2. Introduction to thermal process engineering
  - Thermal separation processes;
  - Mechanisms of separation and parameters for process selection.
3. Evaporation and distillation
  - Evaporating, evaporators;
  - Distillation, distillation of binary and multicomponent mixtures.
4. Rectification
  - Rectification, heat and mass transfer in rectifying section, stripping section;
  - Rectification processes in the McCabe-Thiele diagram.
5. Planning of rectification devices
  - Enthalpy analysis of the rectification process;
  - Modelling of the dynamics of the rectification process.
6. Absorption, adsorption, extraction, crystallization
  - Absorption, binary and multicomponent absorption, adsorption,

večkomponentna absorpcija, adsorpcija, ekstrakcija, večkomponentna ekstrakcija;

- Kristalizacija, desublimacija.

#### 7. Sušenje

- Proces sušenja in kinetika sušenja;  
- Kontaktno, konvektivno in sevalno sušenje, sušenje ob notranji generaciji toplote, zmrzovalno sušenje, sušenje in oblaganje površin.

#### 8. Membranske tehnologije za ločevanje kapljev

- Mikrofiltracija, ultrafiltracija, nanofiltracija;  
- Reverzna osmoza, pervaporacija, ionska izmenjava, elektrodializa.

#### 9. Membranske tehnologije za čiščenje vode in čiščenje odpadne vode

- Priprava pitne vode, priprava visokočiste vode;  
- Čiščenje odpadne vode, razsoljevanje vode.

#### 10. Membranske tehnologije za ločevanje plinov

- Vrste membran, površine in gradiva membran, membranski procesi za ločevanje vodne pare, amonijaka, ogljikovega dioksida, metana in drugih plinov iz plinske zmesi;  
- Čiščenje plinov z membranskimi procesnimi sistemi.

#### 11. Procesno okoljske tehnologije za zbiranje in shranjevanje ogljika

- Procesno okoljske tehnologije za zbiranje in shranjevanje ogljika;  
- Plazemsko uplinjanje, katalitična in biološka metanacija.

#### 12. Bioprocene tehnologije in liofilizacija

- Bioreaktor, kinetika bioprocsov, gretje, hlajenje in sterilizacija bioreaktorja, modeliranje biorektorja.  
- Mehanizmi prenosa toplote in snovi pri liofilizaciji, modeliranje procesa liofilizacije.

#### 13. Procesni inženiring

- Vrednotenje in evalvacija procesnih sistemov, prenos tehnologij v večje in v manjše merilo;  
- Eksrgijska analiza procesnih sistemov.

extraction, multicomponent abstraction;

- Crystallization, desublimation.

#### 7. Drying

- Drying process and drying kinetics;  
- Contact, convective and radiative drying, drying using internal energy generation, freeze drying, drying and coating of surfaces.

#### 8. Membrane technologies for separation of liquids

- Microfiltration, ultrafiltration, nanofiltration;  
- Reverse osmosis, pervaporation, ion exchange, electro dialysis.

#### 9. Membrane technologies for water and wastewater treatment

- Drinking water preparation, high purity water preparation;  
- Wastewater treatment, desalination.

#### 10. Membrane technologies for separation of gases

- Types of membranes, surface area and materials of membranes, membrane processes for separation of steam, ammonia, carbon dioxide, methane and other gases from a gas mixture;  
- Gas cleaning using membrane process systems.

#### 11. Environmental process technologies for carbon capture and storage

- Environmental process technologies for carbon capture and storage;  
- Plasma gasification, catalytic and biological methanation.

#### 12. Bioprocess technologies and lyophilization

- Bioreactor, kinetics of bioprocesses, heating, cooling and sterilization of a bioreactor, bioreactor modelling.  
- Mechanisms of heat and mass transfer in lyophilization, modelling the lyophilization process.

#### 13. Engineering and management of processes

- Evaluation of process systems, scale-up and scale-down of technologies;  
- Exergy analysis of process systems.

#### 14. Micro- and nanoscale process systems

- Process systems with micro- and

<p>14. Mikro in nano procesni sistemi</p> <ul style="list-style-type: none"> <li>- Procesni sistemi z mikro in nanostrukturiranimi superhidrofobnimi, superhidrofinimi in bifilnimi površinami;</li> <li>- Analiza mikro in nano procesnih sistemov s fluorescenčno mikroskopijo in optično pinceto.</li> </ul> <p>15. Študentska predstavitev seminarskega dela iz procesne tehnike</p> <ul style="list-style-type: none"> <li>- Timsko projektno teoretično in eksperimentalno delo;</li> <li>- 3 minutna predstavitev in diskusija.</li> </ul>	<p>nanostructured superhydrophobic, superhydrophilic and biphilic surfaces;</p> <ul style="list-style-type: none"> <li>- Analysis of micro- and nanoscale process systems using fluorescence microscopy and optical tweezers.</li> </ul> <p>15. Student presentation of process engineering seminar work</p> <ul style="list-style-type: none"> <li>- Team projects, theoretical and experimental work;</li> <li>- 3-minute presentation and discussion.</li> </ul>
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### Temeljna literatura in viri/Readings:

<ol style="list-style-type: none"> <li>1. Seader, J.D, Henley, E.J., Roper, D.K., Separation Process Principles with Applications Using Process Simulators, 4th Edition, Wiley, 2006. [COBISS.SI-ID <a href="#">27675653</a>]</li> <li>2. Green D.W., Southard, M. Z., Perry's Chemical Engineers' Handbook, 9th Edition, McGraw-Hill Education; 2018. [COBISS.SI-ID <a href="#">367880</a>]</li> <li>3. Ullmann's Process and Process Engineering, Vol. 1, 2, 3, Wiley – VCH Verlag, Weinheim, 2004- [COBISS.SI-ID <a href="#">25817861</a>]</li> <li>4. Basmadjian D., MassTransfer and Separation Processes, 2nd Edition, CRC Press, 2007. [COBISS.SI-ID <a href="#">28708357</a>]</li> <li>5. Kirk-Othmer separation technology. 2nd ed., Wiley, 2008, 2 zv., <a href="http://www.loc.gov/catdir/enhancements/fy0827/2007039328-t.html">http://www.loc.gov/catdir/enhancements/fy0827/2007039328-t.html</a>. [COBISS.SI-ID <a href="#">10862875</a>]</li> </ol>
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### Cilji in kompetence:

### Objectives and competences:

<p>Cilji:</p> <ol style="list-style-type: none"> <li>1. Podati študentu temeljna znanja s področja procesne tehnike.</li> <li>2. Razumevanje funkcije procesnega inženirstva v okoljskem inženirstvu in trajnostnem razvoju.</li> <li>3. Krepi usposobljenost uporabe inženirskih orodij za reševanje problemov iz procesne tehnike ter utrjevanja inženirskega raziskovalnega pristopa k njihovem reševanju.</li> </ol> <p>Kompetence:</p> <ol style="list-style-type: none"> <li>1. Širitev sposobnosti kritičnega, analitičnega in sintetičnega mišljenja pri reševanju problemov s področja procesne tehnike.</li> </ol>	<p>Objectives:</p> <ol style="list-style-type: none"> <li>1. Educate the student on the basics of process engineering.</li> <li>2. Develop understanding of the role of process engineering in environmental engineering and sustainable development.</li> <li>3. Strengthen the use of engineering tools for problem solving in the field of process engineering and consolidation of engineering research approach to problem solving.</li> </ol> <p>Competences:</p> <ol style="list-style-type: none"> <li>1. Improved capability of critical, analytical and synthetical thinking when solving process engineering</li> </ol>
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<p>Razvijanje novega znanja in razumevanja področja. Razvijanje višjih kognitivnih veščin, povezanih z ustvarjanjem novega znanja na področju procesne tehnike. Obvladovanje temeljnih teoretičnih kakor tudi aplikativnih znanj, ki so bistvena za obvladovanje tehničnega področja procesne tehnike (S2-MAG, P2-MAG).</p> <ol style="list-style-type: none"> <li>2. Usposobljenost za uporabo pridobljenih znanj pri samostojnem reševanju tehničnih problemov v procesni tehniki Sposobnost samostojnega pridobivanja novih znanj in veščin s področja procesne tehnike (S7-MAG, P5-MAG).</li> <li>3. Sposobnost iskanja virov, kritične presoje informacij, samostojnega nadgrajevanja pridobljenih znanj in poglobljanja znanja na področju procesne tehnike. Sposobnost samostojnega izvajanja zahtevnih raziskovalnih, razvojnih, inženirskih in strokovno organizacijskih dela ter sposobnost kreativnega reševanja posameznih nalog na področju procesne tehnike (S8-MAG, P6-MAG).</li> </ol>	<p>problems. Development of new knowledge and comprehension of the field of process engineering. Development of higher cognitive skills, related to the creation of new knowledge in process engineering. Using the fundamental theoretical and applied knowledge, crucial for having command of process engineering technical field (S2-MAG, P2-MAG).</p> <ol style="list-style-type: none"> <li>2. The qualification to use the attained knowledge to autonomously solve technical problems in process engineering. The ability to autonomously acquire new knowledge and skills in the field of process engineering (S7-MAG, P5-MAG).</li> <li>3. The ability to find sources, critically evaluate information, independently upgrade the attained knowledge and deepen the knowledge in the fields of process engineering. The ability to autonomously perform demanding research, developmental, engineering and professionally-organisational work, the ability to creatively solve individual tasks in the field of process engineering (S8-MAG, P6-MAG).</li> </ol>
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**Predvideni študijski rezultati:**

**Intended learning outcomes:**

<p>Znanja:</p> <p>Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja na področju procesne tehnike, ki je osnova za zelo zahtevno strokovno delo (Z2).</p> <p>Spretnosti:</p> <ol style="list-style-type: none"> <li>1. Obvladovanje zelo zahtevnih, kompleksnih delovnih procesov in metodoloških orodij na področju procesne tehnike (S2.1).</li> <li>2. Načrtovanje in vodenje delovnega procesa na podlagi ustvarjalnega</li> </ol>	<p>Knowledge:</p> <p>Thorough theoretical, methodological and analytical knowledge with elements of a research work in the field of process engineering that form a basis for very demanding professional work (Z2).</p> <p>Skills:</p> <ol style="list-style-type: none"> <li>1. Mastering very demanding and complex work processes and methodological tools in process engineering (S2.1).</li> <li>2. Planning and managing of the</li> </ol>
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<p>reševanja problemov, povezanih s procesno tehniko (2.2).</p> <p>3. Sposobnost izvirnih dognanj/stvaritev in kritične refleksije pri reševanju problemov v procesni tehniki (S2.3).</p>	<p>working process on the basis of creative solving of problems that are linked to process engineering (2.2).</p> <p>3. Ability of unique innovations and critical reflections in solving problems in the field of process engineering (S2.3).</p>
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**Metode poučevanja in učenja:**

**Learning and teaching methods:**

<p>P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki s prikazom inženirskih problemov iz področja procesne tehnike.</p> <p>P3 Avditorne vaje, kjer se teoretično znanje iz predavanj podkrepi z računskimi primeri obravnavanih področij procesne tehnike.</p> <p>P4 Laboratorijske vaje z namenskimi eksperimentalnimi progami in didaktičnimi pripomočki za prikaz destilacije, rektifikacije, sušenja, sušenja pri nizkih tlakih, reverzne osmoze, mehčanja vode in oblaganja z razprševalno šobo.</p> <p>P8 Izdelava in predstavitev aplikativnih seminarskih nalog iz področja procesne tehnike.</p> <p>P9 Timsko razvojno raziskovalno projektno delo s predstavitvijo in razpravo.</p> <p>P12 Individualizirane domače naloge v spletni učilnici.</p> <p>P14 Virtualni eksperimenti iz področja procesne tehnike ob uporabi fluorescenčne termografije in optične pincete.</p>	<p>P2 Presenting the content according to the explained system including showcases of problems in process engineering.</p> <p>P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples of process engineering problems.</p> <p>P4 Laboratory exercises with special-purpose didactic devices to showcase distillation, rectification, drying, drying at low pressures, reverse osmosis, water softening and spray nozzle coating.</p> <p>P8 Making and presenting applied seminar exercises in the field of process engineering.</p> <p>P9 Team work (discussion pro and contra, discussion of the studied content, snow ball, structured discussion, brainstorming, project work, etc.).</p> <p>P12 Individualised homework in a web classroom.</p> <p>P14 Virtual experiments in the field of process engineering using fluorescence thermography and optical tweezers.</p>
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**Načini ocenjevanja:**

**Delež/  
Weight**

**Assessment:**

Teoretična vsebine (predavanja, računske naloge).	60,00 %	Theoretical content (lectures, calculation problems).
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Samostojno/skupinsko delo na vajah.	20,00 %	Individual/group work during auditorial exercises.
Seminar.	20,00 %	Seminar.

**Ocenjevalna lestvica:**

**Grading system:**

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

**Iztok Golobič:**

1. SEDMAK, Ivan, MOŽE, Matic, KAMBIČ, Gorazd, **GOLOBIČ, Iztok**. Heat flux analysis and assessment of drying kinetics during lyophilization of fruits in a pilot-scale freeze dryer. *Foods*. Sep. 2023, vol. 12, iss. 18, str. 1-13, ilustr. ISSN 2304-8158. DOI: 10.3390/foods12183399. [COBISS.SI-ID [164380419](#)].
2. VIDOVIČ, Sara, BIZJAK, Alan, SITAR, Anže, HORVAT, Matej, JANKOVIČ, Biljana, **GOLOBIČ, Iztok**. Development of a semi-empirical model for droplet size determination of a three-channel spray nozzle for pellet coating based on the optical method concept. *Processes*. [Online ed.]. Jan. 2022, vol. 10, iss. 1, str. 1-19, ilustr. ISSN 2227-9717. DOI: 10.3390/pr10010086. [COBISS.SI-ID [92405763](#)].
3. SITAR, Anže, ŠKRLEC, Klemen, VOGLAR, Jure, AVANZO, Matej, KOČEVAR, Klemen, CEGNAR, Mateja, IRMAN, Špela, RAVNIK, Jure, HRIBERŠEK, Matjaž, **GOLOBIČ, Iztok**. Effects of controlled nucleation on freeze-drying lactose and mannitol aqueous solutions. *Drying technology*. [Print ed.]. 2018, vol. 36, str. 1263-1272. ISSN 0737-3937. DOI: 10.1080/07373937.2017.139990 [COBISS.SI-ID [21018390](#)].
4. HADŽIĆ, Armin, MOŽE, Matic, ARHAR, Klara, ZUPANČIČ, Matevž, **GOLOBIČ, Iztok**. Effect of nanoparticle size and concentration on pool boiling heat transfer with TiO<sub>2</sub> nanofluids on laser-textured copper surfaces. *Nanomaterials*. [Online ed.]. 2022, vol. 12, iss. 15, str. 1-22, ilustr. ISSN 2079-4991. DOI: 10.3390/nano12152611. [COBISS.SI-ID [117262083](#)].
5. **GOLOBIČ, Iztok**, MOŽE, Matic, SEDMAK, Ivan, SITAR, Anže, ZUPANČIČ, Matevž, KRAJNC, Nike. Analiza proizvodnje obnovljivega plina iz lesne biomase in njegovo injiciranje v prenosno plinovodno omrežje : končno poročilo. Ljubljana: Fakulteta za strojništvo, Laboratorij za toplotno tehniko, 2019. XIV, 128 str., graf. prikazi. [COBISS.SI-ID [16881947](#)].

**Matevž Zupančič:**

1. **ZUPANČIČ, Matevž**, GREGORČIČ, Peter, BUCCI, Mattia, WANG, Chi, AGUIAR, Gustavo Matana, BUCCI, Matteo. The wall heat flux partitioning during the pool boiling of water on thin metallic foils. *Applied thermal engineering*. [Print ed.]. Jan. 2022, vol. 200, str. 1-16, ilustr. ISSN 1359-431 DOI: 10.1016/j.applthermaleng.2021.117638. [COBISS.SI-ID [80131843](#)].
2. MOŽE, Matic, SENEGAČNIK, Matej, GREGORČIČ, Peter, HOČEVAR, Matej, **ZUPANČIČ, Matevž**, GOLOBIČ, Iztok. Laser-engineered microcavity surfaces with a nanoscale superhydrophobic coating for extreme boiling performance.

*ACS applied materials & interfaces*. May 2020, vol. 12, iss. 21, str. 24419-24431, ilustr. ISSN 1944-8244., DOI: 10.1021/acsami.0c01594. [COBISS.SI-ID [14158851](#)].

3. GREGORČIČ, Peter, **ZUPANČIČ, Matevž**, GOLOBIČ, Iztok. Scalable surface microstructuring by a fiber laser for controlled nucleate boiling performance of high- and low-surface-tension fluids. *Scientific reports*. May 2018, vol. 8, f. 1-8, ilustr. ISSN 2045-2322., DOI: 10.1038/s41598-018-25843-5. [COBISS.SI-ID [16034331](#)].
4. SIELAFF, A., MANGINI, D., KABOV, O., RAZA, M. Q., GARIVALIS, A. I., **ZUPANČIČ, Matevž**, GOLOBIČ, Iztok, et al. The multiscale boiling investigation on-board the International Space Station : an overview. *Applied thermal engineering*. [Print ed.]. Mar. 2022, vol. 205, str. 1-23, ilustr. ISSN 1359-4311., DOI: 10.1016/j.applthermaleng.2021.117932. [COBISS.SI-ID [93026307](#)].
5. **ZUPANČIČ, Matevž**, GOLOBIČ, Iztok, MOŽE, Matic, SEDMAK, Ivan, ARHAR, Klara, BERCE, Jure, BUCCI, Mattia, HADŽIĆ, Armin, JEREB, Samo. Optimisation of enhanced freeze drying process for R&D studies : final report. Ljubljana: Faculty of Mechanical Engineering, 2023. III, 23 f., graf. prikazi. [COBISS.SI-ID [140398595](#)].