

# TERMOFLUIDIKA

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Termofluidika
<b>Course title:</b>	Thermofluidics
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni  (od študijskega leta 2023/2024 dalje)	Ni členitve (študijski program)	1. letnik	2. semester	obvezni

<b>Univerzitetna koda predmeta/University course code:</b>	0562665
<b>Koda učne enote na članici/UL Member course code:</b>	3010-V

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45		45			35	5

<b>Nosilec predmeta/Lecturer:</b>	Andrej Bombač, Božidar Šarler
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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</b>	

**usposabljanja:**

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**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 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):**

1. Uvod:
  - cilji in namen predmeta (združena obravnava termodinamskih principov ter principov mehanike tekočin), predstavitev učnega programa, pripomočkov in virov,
  - predstavitev obveznosti študentov in napotki za uspešen študij.
  - pomen termofluidike v tehniki.
2. Struktura termodinamike:
  - termodinamski koncepti, termodinamski zakoni,
  - spremenljivke termodinamskega stanja, eksperimentalne spremenljivke,
  - procesne spremenljivke: delo in toplota.
3. Termodinamske spremenljivke in funkcije:
  - temperatura, volumen, tlak, notranja energija, entalpija, kemični potencial,
  - idealni plin,
  - led, voda in vodna para.
4. Eksperimentalne spremenljivke:
  - koeficient termičnega volumskega raztezka, koeficient stisljivosti,
  - specifična toplota pri konstantnem tlaku, specifična toplota pri konstantnem volumnu,
  - trdnine, kapljevine, plini.
5. Procesne spremenljivke:

1. Introduction:
  - objectives and purpose of the course (combined treatment of thermodynamic principles and principles of fluid mechanics), presentation of the curriculum, tools and resources,
  - presentation of student obligations and directions for successful study.
2. Structure of thermodynamics:
  - thermodynamic concepts, thermodynamic laws,
  - thermodynamic state variables, experimental variables,
  - process variables: work and heat.
3. Thermodynamic variables and functions:
  - temperature, volume, pressure, internal energy, enthalpy, chemical potential,
  - ideal gas,
  - ice, water and water steam.
4. Experimental variables:
  - thermal expansion coefficient, compressibility coefficient,
  - specific heat at constant pressure, specific heat at constant volume,
  - solids, liquids and gasses.
5. Process variables:
  - analysis of external influences on the system,

<ul style="list-style-type: none"> <li>- analiza zunanjih vplivov na sistem</li> <li>- mehansko in druge vrste dela</li> <li>- toplota in mehanizmi prenosa toplote: prevod, konvekcija, sevanje.</li> </ul> <p>6. Zakoni termodinamike:</p> <ul style="list-style-type: none"> <li>- ničti in prvi zakon,</li> <li>- drugi in tretji zakon,</li> <li>- relacije, ki izhajajo iz zakonov termodinamike za zaprte in odprte sisteme.</li> </ul> <p>7. Termodinamski procesi:</p> <ul style="list-style-type: none"> <li>- Izotermni, izentropni, izobarni, izohorni, politropni</li> <li>- procesi z idealnim plinom in vodno paro</li> <li>- idealni in dejanski procesi, analiza in izkoristek procesov.</li> </ul> <p>8. Pomembni termodinamski krožni procesi:</p> <ul style="list-style-type: none"> <li>- Carnotov, Rankinov,</li> <li>- Hladilni procesi in toplotne črpalke,</li> <li>- Ottov and Dieselov proces.</li> </ul> <p>9. Mešanice:</p> <ul style="list-style-type: none"> <li>- mešanica nereaktivnih idealni plinov,</li> <li>- plini v stiku s trdninami, kapljevini in drugimi plini,</li> <li>- procesi z vlažnim zrakom.</li> </ul> <p>10. Hidrostatika</p> <ul style="list-style-type: none"> <li>- tlak v tekočini med mirovanjem,</li> <li>- vzgon in stabilnost plavajočih teles,</li> <li>- tlak v sistemih s togim gibanjem.</li> </ul> <p>11. Osnove dinamike tekočin - nestisljivi tok:</p> <ul style="list-style-type: none"> <li>- Bernoullijeva enačba,</li> <li>- tok nestisljive viskozne tekočine v kanalih in ceveh,</li> <li>- turbulentni tok v ceveh.</li> </ul> <p>12. Osnove dinamike tekočin - stisljivi tok:</p> <ul style="list-style-type: none"> <li>- izotermni, adiabatni in izentropni stisljivi tok,</li> <li>- stisljivi tok v ceveh,</li> <li>- stisljivi tok skozi šobe.</li> </ul> <p>13. Osnove dinamike tekočin - tok okoli teles:</p> <ul style="list-style-type: none"> <li>- mejna plast,</li> <li>- upor,</li> <li>- vzgon.</li> </ul> <p>14. Osnove dinamike tekočin - tok v kanalih:</p> <ul style="list-style-type: none"> <li>- valovi,</li> </ul>	<ul style="list-style-type: none"> <li>- mechanical and other types of work,</li> <li>- heat and mechanisms of heat transfer: conduction, convection, radiation.</li> </ul> <p>6. Thermodynamic laws:</p> <ul style="list-style-type: none"> <li>- zero and first law,</li> <li>- second and third law,</li> <li>- relations that stem from thermodynamics laws for open and closed systems.</li> </ul> <p>7. Thermodynamic processes:</p> <ul style="list-style-type: none"> <li>- Isothermal. isentropic, isobaric, isochoric, polytropic,</li> <li>- processes with ideal gas and water steam,</li> <li>- ideal and actual processes, analysis and process efficiency.</li> </ul> <p>8. Important thermodynamic cycles:</p> <ul style="list-style-type: none"> <li>- Carnot cycle, Rankin cycle,</li> <li>- Cooling processes and heat pumps,</li> <li>- Otto and Diesel cycle.</li> </ul> <p>9. Mixtures:</p> <ul style="list-style-type: none"> <li>- mixture of non-reactive ideal gasses,</li> <li>- gases in contacts with solids, liquids and other gasses,</li> <li>- humid air processes.</li> </ul> <p>10. Hydrostatics:</p> <ul style="list-style-type: none"> <li>- pressure in liquid while stationary,</li> <li>- buoyancy and stability of floating bodies,</li> <li>- pressure in systems with rigid motion.</li> </ul> <p>11. Fluid dynamics fundamentals - incompressible flow:</p> <ul style="list-style-type: none"> <li>- Bernoulli equation,</li> <li>- flow of incompressible viscous fluid in channels and tubes,</li> <li>- turbulent flow in tubes.</li> </ul> <p>12. Fluid dynamics fundamentals - compressible flow:</p> <ul style="list-style-type: none"> <li>- isothermal, adiabatic and isentropic compressible flow,</li> <li>- compressible flow in tubes,</li> <li>- compressible flow through nozzles.</li> </ul> <p>13. Fluid dynamics fundamentals - flow around bodies:</p> <ul style="list-style-type: none"> <li>- boundary layer,</li> <li>- drag,</li> <li>- lift.</li> </ul> <p>14. Fluid dynamics fundamentals - channel flow:</p>
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<ul style="list-style-type: none"> <li>- tok v kanalih s spremenljivo geometrijo,</li> <li>- hidravlični skok.</li> </ul> <p>15. Osnove dvofaznega toka:</p> <ul style="list-style-type: none"> <li>- značilnosti dvofaznih tokov,</li> <li>- dvofazni tokovi v horizontalnih in vertikalnih ceveh,</li> <li>- fazni prehodi.</li> </ul>	<ul style="list-style-type: none"> <li>- waves,</li> <li>- flow in channels with changing geometry,</li> <li>- hydraulic jump.</li> </ul> <p>15. Fundamentals of two-phase flow:</p> <ul style="list-style-type: none"> <li>- characteristics of two-phase flow,</li> <li>- two-phase flow in horizontal and vertical tubes,</li> <li>- phase-change.</li> </ul>
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### **Temeljna literatura in viri/Readings:**

M. Massoud, Engineering Thermofluids: Thermodynamics, Fluid Mechanics, and Heat Transfer, Springer Verlag, Berlin, 2005.

S. R. Turns, Thermal-Fluid Sciences: An Integrated Approach. Cambridge University Press, Cambridge, 2001.

F. W. Schmidt, R.E. Henderson, C. H. Wolgemuth, Introduction to Thermal Sciences: Thermodynamics Fluid Dynamics, Heat Transfer. J.Wiley & Sons, New York, 1993.

C. Marquand, D. Croft, Thermofluids, An Integrated Approach to Thermodynamics and Fluid Mechanics Principles, J.Wiley & Sons, New York, 1994.

### **Cilji in kompetence:**

Cilji:

Spoznati osnovne pojme in principe termofluidike.

Spoznati kritični pristop k razčlenitvi in razumevanju ter zmožnost reševanja inženirskih problemov.

Kompetence:

S11-PAP, P1-PAP: Prepoznavna tehniško relevantnih aplikacij termofluidnih konceptov,

(P8-PAP): ki jih povezujejo termodinamske lastnosti, preobrazbe, sistemi in procesi.

### **Objectives and competences:**

Objectives:

To learn the basic concepts and principles of thermofluidics.

To learn the critical approach to breakdown and understanding as well as the ability to solve engineering problems.

Competences:

S11-PAP, P1-PAP: Recognizing technically relevant applications of thermofluidic concepts,

(P8-PAP) coupled by thermodynamic properties, transformations, systems and processes.

### **Predvideni študijski rezultati:**

Znanja:

Z1: Študent bo po uspešno končanih študijskih obveznostih znal določiti osnovne lastnosti in zakonitosti s področja termodinamike in dinamike tekočin, določiti kontrolni sistem in

### **Intended learning outcomes:**

Knowledge:

Z1: After successfully completing the study obligations, the student will be able to determine the basic properties and laws in the field of thermodynamics and fluid dynamics, determine the

<p>bilanco prehajajočih energij in gibelne količine.</p> <p>Spretnosti:</p> <p>S1.1 Diagnosticiranje in reševanje problemov v različnih specifičnih delovnih okoljih, povezanih s področjem izobraževanja in usposabljanja.</p> <p>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah.</p> <p>S1.3 Osnova za izvirna dognanja/ stvaritve in kritično refleksijo.</p>	<p>control system and the balance of transferred energies and momentum.</p> <p>Skills:</p> <p>S1.1 Diagnosing and solving problems in various specific work environments related to education and training.</p> <p>S1.2 Mastery of demanding, complex work processes with the independent use of knowledge in new work situations.</p> <p>S1.3 Basis for original findings / creations and critical reflection.</p>
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<b>Metode poučevanja in učenja:</b>	<b>Learning and teaching methods:</b>
<p>P1: Avditorni način predavanja.</p> <p>P3: Avditorialne vaje - teroetično znanje podkrepljeno z računskimi primeri.</p> <p>P4: Laboratorijske vaje: laminaren/turbulenten tok, viskoznost tekočine, toplotna kapaciteta, konvektivni prenos toplote.</p> <p>P5: Uporaba študijskega gradiva v obliki učbenika za predavanja.</p> <p>P5: Uporaba študijskega gradiva v obliki učbenika za vaje.</p> <p>P14: Virtualni eksperimenti.</p> <p>P14: Občasna uporaba računalniške animacije.</p>	<p>P1: Auditory lectures.</p> <p>P3: Auditory exercises - Theoretic knowledge backed by computational examples.</p> <p>P4: Lab work: laminar/turbulent flow, fluid viscosity, heat capacity, convective heat transfer.</p> <p>P5: Use of study materials such as a textbook.</p> <p>P5: Use of study materials such as exercise textbook.</p> <p>P14: Virtual experiments.</p> <p>P14: Occasional use of computer animation.</p>

<b>Načini ocenjevanja:</b>	<b>Delež/ Weight</b>	<b>Assessment:</b>
Kolokviji in izpiti. Oceno izpita sestavljata teorija (predavanja)	50,00 %	Colloquia and exams. Exam grade consists of theory (lectures)
in vaje (skupaj z laboratorijskimi).	50,00 %	and exercises (including labs).

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

<p><b>Božidar Šarler:</b></p> <p>1. WANG, Kai, WEN, Shiting, ZAHOOOR, Rizwan, LI, Ming, <b>ŠARLER, Božidar.</b> Method of regularized sources for axisymmetric Stokes flow problems. International journal of numerical methods for heat &amp; fluid flow. 2016, vol. 26, iss. 3/4, str. 1226-1239, ilustr. ISSN 0961-5539. <a href="http://dx.doi.org/10.1108/HFF-">http://dx.doi.org/10.1108/HFF-</a></p>
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- 09-2015-0397, DOI: 10.1108/HFF-09-2015-0397. [COBISS.SI-ID [1206954](#)] Ref 1
2. HATIČ, Vanja, MAVRIČ, Boštjan, **ŠARLER, Božidar**. Simulation of a macrosegregation benchmark with a meshless diffuse approximate method. International journal of numerical methods for heat & fluid flow. 2018, vol. 28, iss. 2, str. 361-380, ilustr. ISSN 0961-5539.  
http://www.emeraldinsight.com/doi/full/10.1108/HFF-04-2017-0143, DOI: 10.1108/HFF-04-2017-0143. [COBISS.SI-ID [1386922](#)]
  3. **ŠARLER, Božidar**. Solution of a two-dimensional bubble shape in potential flow by the method of fundamental solutions. Engineering analysis with boundary elements. [Print ed.]. 2006, vol. 30, no. 3, str. 227-235. ISSN 0955-7997. [COBISS.SI-ID [475131](#)]
  4. PERNE, Matija, **ŠARLER, Božidar**, GABROVŠEK, Franci. Calculating transport of water from a conduit to the porous matrix by boundary distributed source method. Engineering analysis with boundary elements. [Print ed.]. 2012, vol. 36, no. 11, str. 1649-1659. ISSN 0955-7997. DOI: 10.1016/j.enganabound.2012.06.001. [COBISS.SI-ID [2412539](#)]
  5. REUTHER, K., **ŠARLER, Božidar**, RETTENMAYR, Markus. Solving diffusion problems on an unstructured, amorphous grid by a meshless method. International journal of thermal sciences. 2012, vol. 51, str. 16-22. ISSN 1290-0729. DOI: doi:10.1016/j.ijthermalsci.2011.08.017. [COBISS.SI-ID [1998331](#)]

#### **Andrej Bombač:**

1. **BOMBAČ, Andrej**, REK, Zlatko, LEVEC, Janez. *Void fraction distribution in a bisectonal bubble column reactor*. AIChE journal. [Online ed.]. Apr. 2019, vol. 65, iss. 4, str. 1186-1197, ilustr. ISSN 1547-5905.  
<https://onlinelibrary.wiley.com/doi/epdf/10.1002/aic.16534>, DOI: 10.1002/aic.16534. [COBISS.SI-ID [16463387](#)]
2. **BOMBAČ, Andrej**, PIRNAR, Jernej. *Numerical and experimental analyses of a stirred vessel for a large volumetric flow rate of sparged air*. Chinese journal of chemical engineering. 2019, vol. 27, iss. 10, str. 2304-2312, ilustr. ISSN 1004-9541. <https://www.sciencedirect.com/science/article/pii/S1004954118314204?via%3Dihub>, DOI: 10.1016/j.cjche.2019.03.009. [COBISS.SI-ID [16556827](#)]
3. **BOMBAČ, Andrej**, ŠELIH, Zlatko. *Termodinamska analiza procesa na absorpcijskem stolpu pri proizvodnji žveplove kisline*. Ventil : revija za fluidno tehniko in avtomatizacijo. [Tiskana izd.]. jun. 2011, letn. 17, št. 3, str. 226-232, ilustr. ISSN 1318-7279. [COBISS.SI-ID [11908123](#)]
4. PIRNAR, Jernej, ŠIROK, Brane, **BOMBAČ, Andrej**. *Effect of airway surface liquid on the forces on the pharyngeal wall : experimental fluid-structure interaction study*. Journal of biomechanics. [Print ed.]. Oct. 2017, vol. 63, str. 117-124, ilustr. ISSN 0021-9290. [https://ac.els-cdn.com/S0021929017304256/1-s2.0-S0021929017304256-main.pdf?\\_tid=5675a9e4-ace7-11e7-bd92-00000aacb362&acdnat=1507549705\\_3545784e854ed245a0807ee62d15b40d](https://ac.els-cdn.com/S0021929017304256/1-s2.0-S0021929017304256-main.pdf?_tid=5675a9e4-ace7-11e7-bd92-00000aacb362&acdnat=1507549705_3545784e854ed245a0807ee62d15b40d), DOI: 10.1016/j.jbiomech.2017.08.014. [COBISS.SI-ID [15693339](#)]
5. MAJDIČ, Franc, **BOMBAČ, Andrej**. *Raziskave izkoristka plinskega batnega akumulatorja v vodnohidravličnem sistemu*. Ventil : revija za fluidno tehniko in avtomatizacijo. [Tiskana izd.]. apr. 2014, letn. 20, št. 2, str. 118-124, ilustr. ISSN 1318-7279. [COBISS.SI-ID [13453595](#)]