| UČNI NAČRT PREDMETA / COURSE SYLLABUS | |
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| **Predmet:** | Dinamika tekočin |
| **Course title:** | Fluid Dynamics |

| Študijski program in stopnja<br>Study programme and level | Študijska smer<br>Study field | Letnik<br>Academic year | Semester<br>Semester |
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| Senzorske tehnologije, 3. stopnja | / | 1 | 1 |
| Sensor Technologies, 3rd cycle | / | 1 | 1 |

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| **Vrsta predmeta / Course type** | Izbirni / Elective |
| **Univerzitetna koda predmeta / University course code:** | ST3-890 |

| Predavanja<br>Lectures | Seminar<br>Seminar | Sem. vaje<br>Tutorial | Lab. vaje<br>Laboratory work | Druge oblike | Samost. delo<br>Individ. work | ECTS |
|---|---|---|---|---|---|---|
| **15** | **15** | | | **15** | **105** | **5** |

**Navedena porazdelitev ur velja, če je vpisanih vsaj 15 študentov. Drugače se obseg izvedbe kontaktnih ur sorazmerno zmanjša in prenese v samostojno delo. / This distribution of hours is valid if at least 15 students are enrolled. Otherwise the contact hours are linearly reduced and transfered to individual work.*

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| **Nosilec predmeta / Lecturer:** | Prof. dr. Vlado Malačič |
| **Jeziki / Languages: Predavanja / Lectures:** | Slovenščina, angleščina / Slovenian, English |
| **Vaje / Tutorial:** | |

| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | **Prerequisits:** |
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| Zaključena druga stopnja bolonjskega študija ali diploma univerzitetnega študijskega programa. | Completed Bologna second cycle study program or an equivalent pre-Bologna university study program. |

| **Vsebina:** | **Content (Syllabus outline):** |
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| Tekočine. Idealni plin in kapljevine. Hidrostatika stisljive tekočine. Površinske in telesne sile. Gaussov in Stokesov izrek.<br>Kinematika tekočin. Kaj je tok? Tekočinski delci, poti delcev, tokovnice in črte sledila. Eulerjev in Lagrangejev časovni odvod. Razstavitev relativnega gibanja na strižno raztezanje in rotacijo. Vrtinčnost in cirkulacija.<br>Ohranitveni zakoni. Ohranitev volumna in mase tekočine, kontinuitetna enačba, Eulerjeva in Navier-Stokesova gibalna enačba. Enačba mehanske energije in termodinamični zakoni za tekočine. Bernoullijeva enačba.<br>Brezvrtinčni tok. 2D tok, potencial hitrosti in tokovna funkcija. 3D potencialni tok in | Fluids. Perfect gas and liquids. Hydrostatics of compressible media. Surface and body forces. Gauss' and Stokes' theorems.<br>Kinematics of fluids. What are flows? Fluid particles, streamlines, streak lines, particle paths, Euler and Lagrangian time derivative. Decomposition of relative motion in straining rate and rotation. Vorticity and circulation.<br>Conservation laws. Volume and mass conservation, continuity equation, Euler and Navier-Stokes equation of motion. Mechanical energy equation. Thermodynamic laws for fluids. Bernoulli equation.<br>Irrotational flow. 2D flows, velocity potential and stream function. 3D potential flows and axisymmetric stream function. Sources and sinks, |

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| osnosimetrične tokovne funkcije. Izvori in ponori, dipolni tok. Tok mimo neskončno velikega telesa, obtekanje valja in krogle. 2D tok in konformne preslikave.<br>Težni valovi. Linarna (potencialna) teorija površinskih valov na globoki in plitki vodi. Skupinska in fazna hitrost. Stokesov pomik. Interni valovi v stratificirani tekočini, energija internih valov.<br>Laminarni tokovi. Analogija med difuzijo toplote in difuzijo vrtinčnosti. Difuzija vrtinčne sledi, pojemanje linearnega vrtinca.<br>Mejne plasti. Mejna plast ravne plošče, mejna plast pri toku mimo valja in krogle, separacija toka. Sekundarni tok in perturbacijske tehnike.<br>Nestabilnosti. Lastna gibanja. Kelvin-Helmholtzova nestabilnost. Nestabilnost dvojne difuzije, stabilnost vzporednega toka.<br>Turbulentni tok. Procesi v merilu, manjšem od numerične mreže. Reynoldsovo povprečevanje. Vrtinčna viskoznost in mešalna dolžina v toku stratificirane tekočine. Turbulentna mejna plast, koherentne strukture v mejni plasti. Simulacije velikih vrtincev (LES).<br>Numerična dinamika tekočin. Metode končne diference, končnih elementov in končnih volumnov. Shema centralne diference, metoda žabjih skokov. | doublet. Flow past half-body, cylinder and sphere. 2D flows and conformal mapping.<br>Gravity waves. Linear (potential) theory of surface waves in deep and shallow waters. Group and phase velocity. Stokes' drift. Internal waves in continuously stratified fluids, energy of internal waves.<br>Laminar flows. Analogy between heat and vorticity diffusion, diffusion of vortex street, decay of line vortex.<br>Boundary layers. Boundary layer on a flat plate, flow past a cylinder and sphere, separation of flow. Secondary flows and perturbation techniques.<br>Instabilities. Normal modes. Kelvin-Helmholtz instability, double-diffusive instability, stability of inviscid parallel flows.<br>Turbulent flows. Subgrid-scale processes and Reynolds averaging. Eddy viscosity and mixing length in a stratified fluid flow. Turbulent boundary layers, shear flows, coherent structure in a wall layer. Large eddy simulations ( LES) techniques.<br>Computational fluid dynamics. Finite difference, finite element and finite volume methods. Central difference scheme, leap-frog method. |

**Temeljni literatura in viri / Readings:**

Izbrana poglavja iz naslednjih knjig: / Selected chapters from the following books:

- P. K. Kundu, I. M. Cohen. Fluid Mechanics, 2nd Ed., 2002, Academic Press, ISBN:0-12-178251-4.
- D. J. Acheson. Elementary Fluid Dynamics. 1990. Oxford University Press, ISBN 0-19-859679-0.
- A. R. Paterson. A First Course in Fluidb Dynamics,1983. Cambridge University Press, ISBN 0-521-25416-7.
- T. Kambe. Elementary Fluid Mechanics, 2007. World Scientific Publishing, ISBN13 978-981-256-416-0.
- G. Buresti. Elements of Fluid Dynamics, 2012. Imperial College Press. ISBN-13 978-1-84816-888-6.

Izbrani znanstveni članki.

| **Cilji in kompetence:** | **Objectives and competences:** |
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| Cilj predmeta je posredovati študentom obstoječa znanja iz dinamike tekočin.<br>Študentje bodo spoznali osnove stisljivih in predvsem nestisljivih tekočin. Podučili se bodo o laminarnih in turbulentnih tokovih ter osnovnih ohranitvenih zakonih, ki so temelj za geofizikalne tekočine (fizikalno oceanografijo).<br>Študenti bodo razvili sposobnost samostojnega raziskovalnega in razvojnega dela na področju dinamike tekočin, ki vključuje postavitev problema toka tekočine, analitično rešitev za enostavne | The objective of the course is to deliver to the students the existing knowledge of fluid dynamics.<br>Students will be acquainted with fundaments of fluid dynamics of compressible and mostly incompressible flows. They will learn about laminar and turbulent flows, basic conservation laws which represent fundaments for the geophysical fluid flows (physical oceanography).<br>Students will develop the ability to solve independent research and development tasks in the field of fluid dynamics, including the setup of a fluid |

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| tokove tekočin in numerične prijeme za reševanje zapletenejših problemov. | problem to be resolved, analytical tools to find a solution in simple flows and numerical approach to resolve more complex ones. |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
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| Znanje in razumevanje:<br>študenti bodo z uspešno opravljenimi obveznostmi tega predmeta pridobili:<br>• osnovno znanje in razumevanje dinamike tekočin;<br>• analitične in numerične metode za reševanje problemov dinamike tekočin;<br>• osnove za nadaljevanje raziskovalnega dela s področja geofizikalnih tekočin. | Knowledge and understanding:<br>students will acquire upon successfully completing this course:<br>• basic knowledge and understanding of fluid dynamics,<br>• analytical and numerical tools to solve problems in fluid dynamics,<br>• fundamental knowledge for the research in geophysical fluid dynamics. |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
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| predavanja, seminarji, konzultacije, individualno delo | lectures, seminars, consultancy, individual work |

| **Načini ocenjevanja:** | Delež (v %) / Weight (in %) | **Assessment:** |
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| Seminarska naloga | 50 % | Seminar work |
| Ustni zagovor seminarske naloge | 50 % | Oral defense of seminar work |

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

- QUERIN, Stefano, BENSI, M., CARDIN, Vanessa, SOLIDORO, Cosimo, BACER, S., MARIOTTI, Laura, STEL, Fulvio, MALAČIČ, Vlado. Saw-tooth modulation of the deep-water thermohaline properties in the southern Adriatic Sea. Journal of geophysical research, ISSN 0148-0227, 2016, 121, 7, 4585-4600, doi: 10.1002/2015JC011522. [COBISS.SI-ID 3913039]
- GENOV, Tilen, ANGELINI, Valeria, HACE, Ana, PALMISANO, Giuseppe, PETELIN, Boris, MALAČIČ, Vlado, PARI, Sauro, MAZZARIOL, Sandro. Mid-distance re-sighting of a common bottlenose dolphin in the northern Adriatic Sea: insight into regional movement patterns. Journal of the Marine Biological Association of the United Kingdom, ISSN 0025-3154, 2016, l96, 4, 909-914, doi: 10.1017/S0025315415001241. [COBISS.SI-ID 3559759]
- LIČER, Matjaž, SMERKOL, Peter, FETTICH, Anja, RAVDAS, Michalis, PAPAPOSTOLOU, Alexandros, MANTZIAFOU, Anneta, STRAJNAR, Benedikt, CEDILNIK, Jure, JEROMEL, Maja, JERMAN, Jure, PETAN, Sašo, MALAČIČ, Vlado, SOFIANOS, Sarantis. Modeling the ocean and atmosphere during an extreme bora event in northern Adriatic using one-way and two-way atmosphere-ocean coupling. Ocean Science, ISSN 1812-0784, 2016, 12, 71-86, doi: 10.5194/os-12-71-2016. [COBISS.SI-ID 3702095].
- FALCIERI, Francesco Marcello, KANTHA, Lakshmi, BENETAZZO, Alvise, BERGAMASCO, Andrea, BONALDO, Davide, BARBARIOL, Francesco, MALAČIČ, Vlado, SCLAVO, Mauro, CARNIEL, Sandro. Turbulence observations in the Gulf of Trieste under moderate wind forcing and different water column stratification. Ocean Science, ISSN 1812-0784, 2016, 12, 433-449, doi: 10.5194/os-12-433-2016. [COBISS.SI-ID 3806543]
- PETELIN, Boris, KONONENKO, Igor, MALAČIČ, Vlado, KUKAR, Matjaž. Dynamic fuzzy paths and cycles in multi-level directed graphs. Engineering applications of artificial intelligence, , 2014, 37, 194-206, doi: 10.1016/j.engappai.2014.09.012. [COBISS.SI-ID 3224655].