

**UČNI NAČRT PREDMETA / COURSE SYLLABUS**

<b>Predmet:</b>	Meroslovje v senzorskih tehnologijah
<b>Course title:</b>	Metrology in Sensor Technologies

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

**Vrsta predmeta / Course type** Obvezni / Mandatory

**Univerzitetna koda predmeta / University course code:** ST3-900

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo 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 transferred to individual work.*

**Nosilec predmeta and so-predavatelji / Lecturer and co-lecturers:**

Prof. dr. Milena Horvat Prof. dr. Janko Drnovšek Prof. dr. Nives Ogrinc Prof. dr. Ljudmila Benedik Prof. dr. Radmila Milačič Prof. dr. Ester Heath Prof. dr. Jana Žel
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**Jeziki / Predavanja / Lectures:** Slovenski ali angleški / Slovene or English  
**Languages: Vaje / Tutorial:** Slovenski ali angleški / Slovene or English

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

Zaključen študij druge stopnje ustrezne (naravoslovne ali tehniške) smeri ali zaključen študij drugih smeri z dokazanim poznavanjem osnov področja predmeta (pisna dokazila, pogovor).

**Prerequisites:**

Completed second cycle studies in natural sciences or engineering or completed second cycle studies in other fields with proven knowledge of fundamentals in the field of this course (certificates, interview).

**Vsebina:**

Osnove

- Osnovne in izpeljane SI enote, definicije, realizacija, vzdrževanje in diseminacija ali prenos vrednosti, ter sledljivost na mednarodno raven.
- Osnovni pojmi pri podajanju merilnih rezultatov kot so negotovost, sledljivost, meje

**Content (Syllabus outline):**

Basics

- Basic and derived SI units, definition, realization, maintenance and dissemination, or transfer of, and traceability to the international level.
- Basic concepts in delivering measurement results such as uncertainty, traceability, limit of detection, limit of quantification.

<p>občutljivosti, meje kvantifikacije.</p> <ul style="list-style-type: none"> <li>• Tipični viri negotovosti pri meritvah.</li> <li>• Osnovne statistične porazdelitve, ki se uporabljajo pri analizi merilnih rezultatov in negotovosti.</li> <li>• Osnovni pojmi pri prezentaciji merilnih rezultatov (negotovost, korekcija, sistematične napake, ...).</li> <li>• Moderna programska orodja in strojna oprema na področju meroslovja.</li> <li>• EU klasifikacija meroslovnih sistemov/področij (zakonsko, znanstveno, industrijsko), mednarodne organizacije (BIPM, OIML, EURAMET, IAEA).</li> </ul> <p><b>Tehnika</b></p> <ul style="list-style-type: none"> <li>• Splošne informacije o merjenju fizikalnih veličin.</li> <li>• Aplikativni vidiki meroslovja v tehniki.</li> </ul> <p><b>Kemija</b></p> <ul style="list-style-type: none"> <li>• Splošne informacije o meroslovju v kemiji.</li> <li>• Tipični viri negotovosti, ocena in računanje negotovosti, kalibracijski postopki, primeri.</li> </ul> <p><b>Biologija</b></p> <ul style="list-style-type: none"> <li>• Splošne informacije o meroslovju pri bioanalizah (nukleinske kisline, proteini, celice).</li> <li>• Aplikativni vidiki bioanaliz.</li> <li>• Sistemi kakovosti v povezavi z bioanalizami, primeri na senzorskih tehnologijah (npr. gensko spremenjeni organizmi, mikroorganizmi).</li> </ul>	<ul style="list-style-type: none"> <li>• Typical sources of uncertainty in the measurement procedures.</li> <li>• Basic statistical distributions used in the analysis of measurement results and uncertainties.</li> <li>• Basic concepts in the presentation of measurement results (uncertainty, correction, systematic errors, etc.).</li> <li>• Modern software tools and hardware in the field of metrology.</li> <li>• EU classification metrology systems / areas (legal statutory, scientific, industrial), international organizations (BIPM, OIML, EURAMET IAEA).</li> </ul> <p><b>Engineering</b></p> <ul style="list-style-type: none"> <li>• General information on the measurement of physical quantities.</li> <li>• Applied aspects of metrology in physical measurements.</li> </ul> <p><b>Chemistry</b></p> <ul style="list-style-type: none"> <li>• General information on metrology in chemistry.</li> <li>• Typical sources of uncertainty assessment and calculation of uncertainty, calibration procedures, examples from different areas of sensor technology.</li> </ul> <p><b>Biology</b></p> <ul style="list-style-type: none"> <li>• General information on metrology in bioassays (nucleic acids, proteins, cells).</li> <li>• Applied aspects of bioassays.</li> <li>• The quality of the connection with the bioassay; examples on sensor technologies (e.g. genetically modified organisms, microorganisms).</li> </ul>
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### Temeljni literatura in viri / Readings:

<p>Knjiga / Book:</p> <ul style="list-style-type: none"> <li>• R. Laaneots in O. Mathiesen, An Introduction to metrology, TUT Press, Tallin, 2011.</li> <li>• BIPM: "The International System of Units (SI)", 8 izdaja, 2006.</li> <li>• International vocabulary of metrology (VIM), JCGM, 2008.</li> <li>• Eurachem/CITAC, Traceability of Chemical Measurement, 2003.</li> <li>• CITAC/Eurachem Guide; Guide to Quality in Analytical Chemistry, 2002.</li> <li>• Sensors and biosensors in support of EU Directives, Marinella Farré, Lina Kantiani, Sandra Pérez, Damià Barceló, TrAC Trends in Analytical Chemistry, Volume 28, Issue 2, February 2009, Pages 170–185.</li> <li>• Study of Measurement Service and Comparison Needs for an International Measurement Infrastructure for the Biosciences and Biotechnology: Input for the BIPM Work Programme. Rapport BIPM-2011/02.</li> </ul> <p>Revije / Periodicals:</p> <ul style="list-style-type: none"> <li>• AQUAL, Analytical Quality and Accreditation.</li> <li>• Metrologia.</li> <li>• Journals related to analytical chemistry (JAAS, Analitica chimica Acta, Analytical Chemistry) and others</li> </ul>
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relevant for the application of measurement science in industry, food production, environment and environmental health.

- Pregledni članki, izbor v tekočem letu/Review articles, yearly selection.

### **Cilji in kompetence:**

Vpeljati študente v osnove:

- uporabe meroslovnih konceptov pri fizikalnih, kemijskih in bioloških meritvah,
- razumevanja konceptov sledljivosti, negotovosti in primerljivosti merskih rezultatov pri fizikalnih, kemijskih in bioloških meritvah,
- razumevanje sistemov kakovosti na področju merjenj v kemiji, tehniki in biologiji,
- spoznavanja meroslovnih sistemov, hierarhičnih zgradb in mednarodnih organizacij na področju meroslovja v kemiji, tehniki in biologiji,
- EU klasifikacije in vpetosti slovenskega sistema v mednarodni sistem merjenj na področju kemije, tehnike in biologije,
- poglobljenega vpogleda v vse faze merilnega postopka kar bo omogočilo reševanje problemov na področju merjenj v kemiji, fiziki in biologiji.
- SI sledenje meritev na področju ugotavljanja vsebnosti organskih in anorganskih onesnažil in ostalih spojin ter radionuklidov v okolju, zdravju in industriji,
- SI sledenje meritev naravnih vsebnosti stabilnih izotopov lahkih elementov in uporaba izotopsko obogatenih materialov,
- SI sledenje meritev na področju ugotavljanja vsebnosti nukleinskih kislin, proteinov za področje varne hrane in zdravja ljudi.

Kompetence:

- pridobivanje sposobnosti celovitega reševanja merilnih problemov,
- vključevanja znanja v gradnjo hipotez za reševanje problemov, ciljano k temi doktorata,
- sposobnost apliciranja meroslovnih konceptov pri merjenju v okviru raziskovalnega dela,
- obvladovanje sistemov sledljivosti do SI enot oz. referenčnih vrednosti pri meritvah.

### **Objectives and competences:**

To introduce students to the basics of:

- using metrological concepts in physical, chemical and biological measurements,
- understanding the concepts of traceability, uncertainty and comparability of measurement results in physical, chemical and biological measurements,
- understanding of quality systems in the field of measurements in chemistry, engineering and biology,
- knowledge of metrology systems, hierarchical structures and international organizations in the field of metrology in chemistry, engineering and biology,
- EU classification and integration of Slovenian system into the international system of measurements in chemistry, engineering and biology,
- in-depth insight into all phases of the measurement procedure, which will allow solving problems in the field of measurements in chemistry, engineering and biology,
- SI traceable measurement in the determination of organic and inorganic pollutants and other compounds, and radionuclides in the environment, health and industry,
- SI traceable measurements of natural levels of stable isotopes of light elements and the use of isotopically enriched materials,
- SI traceable measurement in the determination of nucleic acids, proteins in the field of food safety and human health.

Competencies:

- acquiring the ability of solving measurement problems,
- integration of knowledge in designing hypotheses for solving the problems in student's doctoral research work,
- metrological concepts, administered in the measurement carried out by the course of candidate's research work,
- management systems of traceability to SI units or

reference values for measurements carried out by a candidate.

#### **Predvideni študijski rezultati:**

Študent z uspešno zaključenim predmetom bo pridobil osnovno znanje na naslednjih področjih:

- obvladovanje raziskovalnih metod, postopkov in procesov, usmerjenih h kritičnemu ovrednotenju dobljenih rezultatov,
- poznavanje konceptov sledljivosti in negotovosti,
- razumevanje izvora napak in njihovo pravilno ovrednotenje,
- sposobnost uporabe najnovjših znanj in konceptov na področju meroslovja,
- vključevanje teh znanj pri reševanju problemov v sklopu disertacije.

#### **Intended learning outcomes:**

The student with the successful completion of the course will acquire basic knowledge in the following areas:

- management of research methods, procedures and processes that will be directed towards critical evaluation of the results obtained,
- knowledge of the concepts of traceability and uncertainty,
- understanding the origin of errors and their proper evaluation,
- ability to use the latest skills and concepts in the field of metrology,
- integration of these skills in problem solving in the context of the dissertation.

#### **Metode poučevanja in učenja:**

Interaktivno delo s študentom.

Predmet je sestavljen iz osnov meroslovja in treh modulov: meroslovje v kemiji, biologiji in tehniki.

Poudarek je predvsem na reševanju realnih problemov, ki so povezani z raziskovalnim delom kandidata.

#### **Learning and teaching methods:**

Interactive work with students.

The course consists of basic metrology and three modules: metrology in chemistry, biology and engineering. The focus is on solving real problems that are related to the research work of the student.

Delež (v %) /

Weight (in %)

#### **Načini ocenjevanja:**

#### **Assessment:**

Seminarska naloga.

30 %

Seminar.

Ustni izpit.

30 %

Oral examination.

Zagovor projekta - reševanje primera.

40 %

Presentation of the project - solving the case.

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

- ŽIVKOVIĆ, Igor, FAJON, Vesna, TULASI, Delali, OBU, Kristina, HORVAT, Milena. Optimization and measurement uncertainty estimation of hydride generation-cryogenic trapping-gas chromatography-cold vapor atomic fluorescence spectrometry for the determination of methylmercury in seawater. *Marine Chemistry*, ISSN 0304-4203. [Print ed.], 2017, vol. 193, str. 3-7, doi: [10.1016/j.marchem.2017.03.003](https://doi.org/10.1016/j.marchem.2017.03.003).
- RADEJ, Blaž, DRNOVŠEK, Janko, BEGEŠ, Gaber. An overview and evaluation of quality-improvement methods from the manufacturing and supply-chain perspective. *Advances in production engineering & management*, ISSN 1854-6250, Dec. 2017, vol. 12, no. 4, str. 388-400, ilustr. [http://apem-journal.org/Archives/2017/APEM12-4\\_388-400.pdf](http://apem-journal.org/Archives/2017/APEM12-4_388-400.pdf), doi: [10.14743/apem2017.4.266](https://doi.org/10.14743/apem2017.4.266).
- DUNN, Peter John, GOENAGA-INFANTE, Heidi, GOREN, A. C., ŠIMŠEK, A., BILSEL, M., OGRINC, Nives, ARMISHAW, P., HAI, L. CCQM-K140 : carbon stable isotope ratio delta values in honey. *Metrologia*, ISSN 0026-1394, 2017, vol. 54, tech. supp. , str. 08005-1-08805-25, doi: [10.1088/0026-1394/54/1A/08005](https://doi.org/10.1088/0026-1394/54/1A/08005).

- HEATH, Ester, ČESEN, Marjeta, ŠČANČAR, Janez, NOVAKOVIĆ, Srdjan, MISLEJ, Vesna, STRAŽAR, Marjetka, KOSJEK, Tina, et al. First inter-laboratory comparison exercise for the determination of anticancer drugs in aqueous samples. *Environmental science and pollution research international*, ISSN 0944-1344. [Print ed.], 2016, vol. 23, no. 15, str. 14692-14704, doi: [10.1007/s11356-015-4982-9](https://doi.org/10.1007/s11356-015-4982-9).
- PAVŠIČ, Jernej, DEVONSHIRE, Alison S., BLEJEC, Andrej, FOY, Carole A., HEUVERSWYN, Fran Van, JONES, Gerwyn M., SCHIMMEL, Heinz, ŽEL, Jana, HUGGETT, Jim F., REDSHAW, Nicholas, KARCZMARCZYK, Maria, MOZIOGLU, Erkan, AKYÜREK, Sema, AKGÖZ, Müslüm, MILAVEC, Mojca. Inter-laboratory assessment of different digital PCR platforms for quantification of human cytomegalovirus DNA. *Analytical and bioanalytical chemistry*, ISSN 1618-2642, 2017, vol. 409, iss. 10, str. 2601-2614. <http://dx.doi.org/10.1007/s00216-017-0206-0>, doi: 10.1007/s00216-017-0206-0