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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Kompleksni merilni sistemi | | | | | | | | | | | | | | |
| **Course title:** | | | Complex measurement systems | | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| Podiplomski magistrski študijski program druge stopnje Elektrotehnika | | | | | Robotika | | | | | | | | 1 | | 1 | | |
| 2nd cycle masters study programme in Electrical Engineering | | | | | Robotics | | | | | | | | 1 | | 1 | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | Obvezni-strokovni / Compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | 64233 | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| **45** |  | | | **30** | | |  | | | |  | | | **75** | |  | **6** |
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| **Nosilec predmeta / Lecturer:** | | | | | Janko Drnovšek, Jovan Bojkovski, Dušan Agrež | | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | **slovenščina, angleščina /Slovene, English** | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | **Slovenščina, angleščina /Slovene, English** | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| Vpis v letnik. | | | | | | | | |  | Enrolment in the year of the course. | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| a) splošni principi kompleksnih merilnih sistemov in merljivost pojavov (uvod v kompleksne merilne sisteme, omejitve pri merjenju električnih in neelektričnih veličin, merljivost nemerljivih parametrov (bolečina, smrad, utrujenost, …))  b) osnove kvantne metrologije (kvantni pojavi, povezava med definicijo in realizacijo fizikalnih veličin, fizikalne konstante in uporaba v merilnih sistemih)  c) prilagajanje signalov in zmanjševanje šuma v elektronskih merilnih sistemih (ojačenje, mostična vezava, filtriranje,…)  d) plavajoče meritve in zaščita (načini izvajanja plavajočih meritev v odvisnosti od merjenega signala, načini izvedbe zaščit, prikazi dobre prakse izvedbe zaščite, varnost)  e) merilna točnost, negotovost in obdelava rezultatov (osnove merilne točnosti, sledljivosti, viri negotovosti, obdelava in prikaz merilnih rezultatov)  f) merjenja po področjih (medicina, električna varnost, okolje, energetika, ...) | | | | | | | |  | | a) common principles of complex measurement systems and measurability ( introduction to complex measurements systems, limitation in measurement of electrical and non-electrical quantities, measurements of non-measurable parameters (pain, odour, tiredness, …)  b) basics of quantum metrology (quantum phenomena, linkage between definition and realization of physical quantities, physical constants and usage in measurement systems)  c) signal adjustment and filtering in electronic measurement systems (amplification, bridge, filtering, …)  d) floating measurements and guard (different principles of floating measurement depending on the measurement signal, how to properly guard measurement system, safety and security when measuring)  e) measurement accuracy, uncertainty and data processing (basics of accuracy, traceability, sources of uncertainty, data processing and presentation of measuring results)  f)specific measurements (medicine, electrical safety, environment, energetics, ...) | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. Drnovšek, J.; Bojkovski, J,: Kompleksni merilni sistemi, Ljubljana: Fakulteta za elektrotehniko 2012 2. Lang, T.T: Computerized Instrumentation. New York: John Wiley & Sons Inc. 1991 3. Carr, J.J.: Elements of Electronic Instrumentation and Measurement. 3. izdaja. Englewood Cliffs, New Jersey: Prentice-Hall. 1996 4. Morris, A.S.: The essence of measurement. London, New York: Prentice-Hall. 1996 5. Lang, T.T: Electronics of measuring systems. Chichester, New York: John Wiley & Sons Inc. 1994 6. Bentley, J.P.: Principles of Measurement Systems. 3. izdaja. New York: John Wiley & Sons Inc. 1995 7. Morris, A.S.: Measurement and Instrumentation Principles. Oxford: Butterworth-Heinemann. 2001 8. Regtien, P.P.L.: Measurement Science for Engineers. London, Sterling: Kogan Page Science. 2004 | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| a) razširiti in poglobiti znanje o kompleksnih merilnih sistemih ter merljivosti pojavov (vplivni parametri, fizikalne omejitve, vedenje o sodobnih nanosenzorjih ter omejitvami pri uporabi le-teh, ...)  b) seznaniti se z osnovami kvantne metrologije (trenutno stanje in prihodnji razvoj skozi uporabo "časovnih diagramov" (roadmap) za načrtovanje  c) proučiti zahteve prisotne pri prilagajanju signalov različnih vrst (frekvenca, amplituda, moč, .. ) in zmanjševanju šuma v elektronskih merilnih sistemih  d) ugotoviti osnovne parametre potrebne za uspešno izvajanje plavajočih meritev kot tudi optimalno izvedbo zaščit  e) podrobno spoznati sodobne definicije vezane na izračune merilnih negotovosti (simulacija s pomočjo Monte-Carlo metode), kot tudi obdelavo in prikazovanje merilnih rezultatov  f) ugotoviti ključne parametre pri zagotavljanju kakovosti na posameznih področjih kot so medicina, električna varnost, okolje, energetika, ... | |  | | a) broaden knowledge about complex measurement systems and measurability (influence parameters, physical limits, ...)  b) using roadmaps to establish current state of the art in the field of quantum metrology  c) define requirements for data adjustment of signals (frequency, amplitude, power, ...)  d) optimal guarding of measurement systems, basic and advanced parameters of floating measurements  e) modern definitions of measurement uncertainty (simulation using Monte-Carlo method), data processing and presentation  f) key parameters in quality assurance in different fields (medicine, electrical safety, environment, energy), ... | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| Znanje in razumevanje:  napredni pojmi iz področja kompleksnih merilnih sistemov, razumevanje ustroja kvantne realizacije osnovnih fizikalnih veličin, z poudarkom na realizaciji enote Kelvin, pojmi povezani z prilaganjem signalov in zmanjševanjem šuma, napredne metode za analizo in prikazovanje merilnih rezultatov, razumevanje merjenj na posameznih področjih kot so medicina, zaščita okolja, ... | | |  | Knowledge and understanding:  Advanced knowledge about complex measurement system, understanding quantum realization of basic physical quantities with emphasize on unit Kelvin, understanding signal conditioning and noise filtering, advanced methods for result presentation, understanding measurements in different fields like medicine, environment, ... | |
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| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| predavanja, seminarji, laboratorijske vaje | | |  | Lectures, seminars, laboratory exercises | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Način: laboratorijske vaje, pisni izpit, ustni izpit  Ocene od 1 do vključno 5 so negativne, ocene od vključno 6 do 10 so pozitivne.  Pozitivna ocena laboratorijskih vaj je pogoj za pristop k izpitu.  Prispevki k oceni:   * laboratorijske vaje, * pisni izpit, * ustni izpit. | 40%  30%  30% | | | | Type: laboratory exercises, written exam, oral exam.  Negative grades: from 1 to 5, positive grades: from 6 to 10.  Positive evaluation of laboratory exercises is a prerequisite for the exam.  Contributions to the final grade:   * laboratory exercises, * Written exam, * Oral examination. |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. BEGUŠ, Samo, BOJKOVSKI, Jovan, DRNOVŠEK, Janko, GERŠAK, Gregor. Magnetic effects on thermocouples. Measurement science & technology, 2014, vol. 3, no. 25, str. 1-11. 2. MIKLAVEC, Andraž, PUŠNIK, Igor, BATAGELJ, Valentin, DRNOVŠEK, Janko. A large aperture blackbody bath for calibration of thermal imagers. Measurement science & technology, 2013, vol. 2, no. 24, str. 1-8. 3. AGREŽ, Dušan. Estimation of parameters of the weakly damped sinusoidal signals in the frequency domain. Computer standards & interfaces, 2011, vol. 33, no. 2, str. 117-121. 4. ŽUŽEK, Vincencij, BATAGELJ, Valentin, DRNOVŠEK, Janko, BOJKOVSKI, Jovan. Effect of bushings in thermometric fixed-point cells. Measurement, Jan. 2016, vol. 78, str. 289-295. 5. BATAGELJ, Valentin, ŽUŽEK, Vincencij, DRNOVŠEK, Janko, BOJKOVSKI, Jovan. A numerical and experimental investigation of the heat losses in thermometric fixed-point cells. International journal of heat and mass transfer, Jun. 2015, vol. 85, str. 321-335. | | | | | |