

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Merilni praktikum
Course title:	Measurement practicum
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Mehatronika (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Energetsko strojništvo (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Procesno strojništvo (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje strojev in naprav (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje industrijskih sistemov (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Proizvodne tehnologije (smer)	2. letnik	2. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Industrijsko inženirstvo (smer)	2. letnik	2. semester

Univerzitetna koda predmeta/University course code: 0562719

Koda učne enote na članici/UL Member course code: 3022-V

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
30		30			65	5

Nosilec predmeta/Lecturer: Jože Kutin

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	Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.
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Vsebina:

1. Merjenje in meroslovni sistem – temeljna izhodišča 1
 - Pomen inženirskega eksperimentiranja
 - Področje meroslovja
 - Vplivni dejavniki v procesu merjenja
2. Merjenje in meroslovni sistem – temeljna izhodišča 2
 - Merilni pogrešek vs. merilna negotovost
 - Celovit merilni rezultat
 - Meroslovna sledljivost
 - Proces umerjanja oz. kalibracije
 - Mednarodni sistem merskih enot SI
3. Signalne značilnosti merilnega sistema
 - Analogni in digitalni merilni signali
 - Prenos merilnih signalov
 - Šum oz. motnje pri merjenju
4. Temeljni gradniki merilnih sistemov 1
 - Funkcija merilnega zaznavala
 - Pregled fizikalnih principov merilnih zaznaval
 - Neelektrična in električna merilna zaznavala za merjenja v strojništvu
5. Temeljni gradniki merilnih sistemov 2
 - Funkcija merilnega pretvornika
 - Merilni ojačevalnik
 - Frekvenčno sito oz. filter
6. Temeljni gradniki merilnih sistemov 3
 - Analogno-digitalni pretvornik (merilna kartica)
 - Vplivni parametri pri njihovi izbiri in uporabi, npr. frekvenca vzorčenja, število bitov
 - Virtualna instrumentacija
7. Statične lastnosti merilnih sistemov 1
 - Statične lastnosti merilnih sistemov
 - Merilno območje, merilni razpon
 - Merilna značilnica, merilni model, merilna funkcija
 - Merilna občutljivost
8. Statične lastnosti merilnih sistemov 2
 - Merilna točnost, merilna natančnost
 - Nelinearnost, histereza, ponovljivost
 - Ločljivost odčitka
 - Zunanje vplivne veličine
 - Časovna stabilnost
9. Dinamske lastnosti merilnih sistemov 1
 - Dinamični merilni pogrešek
 - Eksperimentalno določanje dinamskih lastnosti merilnih sistemov
 - Dinamični generatorji merjene veličine
10. Dinamske lastnosti merilnih sistemov 2
 - Dinamske lastnosti merilnih sistemov
 - Časovna konstanta, odzivni čas

Content (Syllabus outline):

1. Measurement and metrological system – fundamentals 1
 - Importance of engineering experimentation
 - Field of metrology
 - Influence factors in measurement process
2. Measurement and metrological system – fundamentals 2
 - Measurement error vs. measurement uncertainty
 - Complete measurement result
 - Metrological traceability
 - Calibration process
 - International system of units (SI)
3. Signal characteristics of measuring systems
 - Analog and digital measurement signals
 - Transmission of measurement signals
 - Noise and disturbances in measurements
4. Components of measuring systems 1
 - Role of the sensor
 - Review of physical principles of sensors,
 - Non-electrical and electrical sensors for measurements in mechanical engineering
5. Components of measuring systems 2
 - Role of measuring transmitter
 - Measuring amplifiers
 - Frequency filters
6. Components of measuring systems 3
 - Role of analog-digital converter (data acquisition device)
 - Influential parameters on their selection and application, e.g., sampling frequency, number of bits.
 - Virtual instrumentation
7. Static characteristics of measuring systems 1
 - Static characteristics of measuring systems
 - Measuring range, measuring span
 - Measuring characteristic, measurement model, measurement function
 - Measurement sensitivity
8. Static characteristics of measuring systems 2
 - Measurement accuracy, precision
 - Nonlinearity, hysteresis, repeatability
 - Resolution
 - External influential quantities
 - Time stability
9. Dynamic characteristics of measuring systems 1
 - Dynamic measurement error
 - Experimental determination of dynamic measurement characteristics
 - Dynamic generators of measured quantity
10. Dynamic characteristics of measuring systems 2

<ul style="list-style-type: none"> - Uporabno frekvenčno območje 11. Vrednotenje merilnih rezultatov 1 <ul style="list-style-type: none"> - Metodologija vrednotenja merilnih rezultatov - Prepoznavanje potencialnih vplivov - Vplivi lastnosti in načina uporabe merilnega sistema 12. Vrednotenje merilnih rezultatov 2 <ul style="list-style-type: none"> - Statistično vrednotenje merilnih rezultatov - Ocena srednje vrednosti - Ocena raztrosa izmerkov, raztrosa srednje vrednosti 13. Vrednotenje merilnih rezultatov 3 <ul style="list-style-type: none"> - Skupna standardna in razširjena merilna negotovost - Vrednotenje rezultatov neposrednih merjenj - Vrednotenje rezultatov posrednih merjenj - Vrednotenje rezultatov primerjalnih merjenj 14. Obvladovanje merilnega sistema in procesa merjenja – izbrani primeri 1 <ul style="list-style-type: none"> - Izbrani primeri merjenj v strojništvu - Merjenje deformacij, sil, navora itd. z uporovnimi merilnimi lističi - Konfiguracija merilnega sistema - Vplivne veličine na kakovost merjenja 15. Obvladovanje merilnega sistema in procesa merjenja – izbrani primeri 2 <ul style="list-style-type: none"> - Merjenje mehanskih nihanj, tlakov itd. s piezoelektričnimi merilnimi zaznavali - Konfiguracija merilnega sistema - Vplivne veličine na kakovost merjenja - Drugi možni primeri: merjenje z induktivnimi, kapacitivnimi, optičnimi merilnimi sistemi 	<ul style="list-style-type: none"> - Dynamic characteristics of measuring systems - Time constant, response time - Useful frequency range 11. Evaluation of measurement results 1 <ul style="list-style-type: none"> - Methodology for evaluation of measurement results - Recognizing potential influences - Influences related to characteristics of measuring system and the way of its usage 12. Evaluation of measurement results 2 <ul style="list-style-type: none"> - Statistical evaluation of measurement results - Estimating the mean value - Estimating the scatter of measured values, scatter of the mean value 13. Evaluation of measurement results 3 <ul style="list-style-type: none"> - Combined standard and expanded measurement uncertainty - Evaluation of results of direct measurements - Evaluation of results of indirect measurements - Evaluation of results of comparison measurements 14. Management of measuring system and measurement process – case study 1 <ul style="list-style-type: none"> - Selected cases of measurements in mechanical engineering - Measurements of deformation, force, torque, etc., using strain gauges - Configuration of measuring system - Influences on quality of measurement 15. Management of measuring system and measurement process – case study 2 <ul style="list-style-type: none"> - Measurements of vibration, pressure, etc., using piezoelectric sensors - Configuration of measuring system - Influences on quality of measurement - Other potential cases: measurements using inductive, capacitive, optical measuring systems
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Temeljna literatura in viri/Readings:

1. JCGM 200:2012 – International vocabulary of metrology – Basic and general concepts and associated terms.
2. Bentley, J. P.: Principles of measurement systems. Pearson Prentice Hall, 2005.
3. Doebelin, E. O.: Measurement systems – Application and design. McGraw-Hill, 200
4. Morris, A. S.: Measurement & instrumentation principles. Butterworth-Heinemann, 2001.
5. Hashemian, H. M.: Sensor performance and reliability. ISA, 2004.
6. Busch-Vishniac, I. J.: Electromechanical sensors and actuators. Springer, 1999.
7. JCGM 100:2008 – Evaluation of measurement data – Guide to the expression of uncertainty in measurement.
8. Montgomery, D. C., Runger, G. C.: Applied statistics and probability for engineers. Wiley, 2013.

Cilji in kompetence:

Objectives and competences:

Cilji:	Objectives:
1. Spoznati področje meroslovja in temeljne meroslovne pojme	1. To familiarize with the field of metrology and metrological terminology
2. Spoznati temeljne gradnike in izhodišča načrtovanja	2. To familiarize with components and design of

<p>merilnih sistemov s področja merjenj v strojništvu</p> <ol style="list-style-type: none"> 3. Razumeti ključne parametre za popis statičnih in dinamičnih lastnosti merilne opreme in merilnih sistemov 4. Spoznati vplivne dejavnike v procesu merjenja in izhodišča vrednotenja merilnih rezultatov <p>Kompetence:</p> <ol style="list-style-type: none"> 1. S10-PAP: Sposobnost strokovnega sporazumevanja in pisnega izražanja na področju meroslovja. 2. P4-PAP: Pozna osnovne merilne instrumente in merilne verige za merjenje osnovnih veličin na področju strojništva. 3. S1-PAP + S5-PAP + P9-PAP: Sposobnost uporabe pridobljenih znanj pri načrtovanju merilnih sistemov, izvajanju meritev in vrednotenju merilnih rezultatov. 	<p>measuring systems in the field of measurements in mechanical engineering</p> <ol style="list-style-type: none"> 3. To understand key parameters for description of static and dynamic characteristics of measuring instruments and measuring systems 4. To familiarize with influence parameters in measurement process and fundamentals of evaluation of measurement results <p>Competences:</p> <ol style="list-style-type: none"> 1. S10-PAP: The ability to communicate professionally and express oneself in writing.. 2. P4-PAP: Knowing the basic measuring instruments and measuring chains used to measure the basic quantities in the field of mechanical engineering. 3. S1-PAP + S5-PAP + P9-PAP: The ability to use the acquired knowledge for designing of measuring systems, performing measurements and evaluation of measurement results
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Predvideni študijski rezultati:

<p>Znanja:</p> <p>Z1: Poglobljeno strokovno teoretično in praktično znanje na določenem področju, podprto s širšo teoretično in metodološko osnovo.</p> <p>- Znanje o procesu merjenja, s poudarkom na metodologiji izbire merilne opreme, načrtovanju merilnih sistemov ter obvladovanju kakovosti merjenj in vrednotenja merilnih rezultatov</p> <p>Spretnosti:</p> <p>S1.1 Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo tudi uporabo metodoloških orodij.</p> <p>- Načrtovanje merilnih sistemov želene merilne točnosti, dinamičnih lastnosti itd.</p> <p>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah.</p> <p>- Obvladovanje izbire merilne opreme in vplivov na proces merjenja</p> <p>S1.3 Diagnosticiranje in reševanje problemov v različnih specifičnih delovnih okoljih, povezanih s področjem izobraževanja in usposabljanja.</p> <p>- Reševanje problemov s področja vrednotenja merilnih rezultatov.</p>
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Intended learning outcomes:

<p>Outcomes:</p> <p>Z1: Thorough professional theoretical and practical knowledge in a selected field of expertise that is supported with a broad theoretical and methodological basis.</p> <p>- Knowledge about measurement processes with emphasis on methodology of selection of measuring instruments, design of measuring systems, management of measurement quality and evaluation of measurements results.</p> <p>Skills:</p> <p>S1.1 Executing complex operationa-professional tasks that incorporate usage of methodological tools.</p> <p>- Design of measuring systems with target measurement accuracy, dynamic characteristics, etc.</p> <p>S1.2 Mastering demanding and complex work processes by independent usage of knowledge in new working situations.</p> <p>- Management of selection of measuring instruments, management of influences on measurement process.</p> <p>S1.3 Problem diagnostics and solving in different and specific working environments that are linked to the teaching and training content.</p> <p>- Solving problems related to evaluation of measurement results.</p>
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Metode poučevanja in učenja:

Learning and teaching methods:

<p>P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.</p> <p>P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki (merilni sistemi s področja merjenj v strojništvu, računalniško nadzorovani merilni sistemi, merilni sistemi za statična in dinamična merjenja).</p> <p>P6 Interaktivna predavanja</p> <p>P9 Skupinsko delo</p> <p>P14 Virtualni eksperimenti</p> <p>P15 Uporaba video vsebin kot priprava na predavanja in vaje</p>	<p>P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases.</p> <p>P4 Laboratory exercises with special-purpose didactic devices (measuring systems applicable in mechanical engineering, computer controlled measuring systems, measuring systems for static and dynamic measurements).</p> <p>P6 Interactive lectures.</p> <p>P9 Team work</p> <p>P14 Virtual experiments.</p> <p>P15 Application of videos for preparations to the lectures and exercises.</p>
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Načini ocenjevanja:	Delež/Weight	Assessment:
Pisno ocenjevanje teorije	45,00 %	Written examination of theory
Praktično delo na vajah	45,00 %	Practical work on exercises
Ustni zagovor	10,00 %	Oral examination

Reference nosilca/Lecturer's references:

Jože Kutin

- BOBOVNIK, Gregor, **KUTIN, Jože**. Experimental identification and correction of the leakage flow effects in a clearance-sealed piston prover. Metrologia, 2019, vol. 56, nr. 1, str. 1-9 [tipologija 01, SCI]
- SVETE, Andrej, BAJSIČ, Ivan, **KUTIN, Jože**. Investigation of polytropic corrections for the piston-in-cylinder primary standard used in dynamic calibrations of pressure sensors. Sensors and actuators. A, Physical, ISSN 0924-4247, May 2018, vol. 274, str. 262-271 [tipologija 1.01, SCI]
- KUTIN, Jože**, BOBOVNIK, Gregor, BAJSIČ, Ivan. Dynamic effects in a clearance-sealed piston prover for gas flow measurements. Metrologia, 2011, vol. 48, no. 3, str. 123-132 [tipologija 1.01, SCI]
- KUTIN, Jože**, BAJSIČ, Ivan. Characteristics of a dynamic pressure generator based on loudspeakers. Sensors and actuators. A, Physical, Jul. 2011, vol. 168, iss. 1, str. 149-154 [tipologija 1.01, SCI]
- BOBOVNIK, Gregor, **KUTIN, Jože**. Direct comparison of the DHMZ and LMPS gas flow reference standards in the range between (5-70) sl/min : final report. Ljubljana: Faculty of Mechanical Engineering, Laboratory of Measurements in Process Engineering, 2019. [tipologija 2.12]