1. GENERAL INFORMATION

Study programme title	University graduate study programme in mining engineering Subprogrammes Mining engineering and Geotechnical engineering		
Course title	Measurement Technology	**Semester**	I.
Teacher	Assoc.prof. Dalibor Kuhinek, PhD	**Course code**	
Course type	☐ obligatory ☒ elective	**ECTS**	3,5
Location	Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, Zagreb		
Language	☐ Croatian ☒ English		

Class type	Weekly hours	Teaching staff	Office hours	Room	E-mail
Class	2	Assoc.prof. Dalibor Kuhinek, PhD	Thursday 14-16 p.m.	P6 208	
Practice	1	Ana Hanić, PhD	Thursday 14-16 p.m.	P6 207	
Field lecture					

E-learning level	1	**Percentage of on-line class (max. 20%)**	5 %

2. COURSE DESCRIPTION

Course aims	Understanding the basic concepts, basic laws and principles relating to the measurement techniques. Use of basic and advanced statistical tools to analyze the measurement results. Calculating measurement errors of indirect measurements. Use signal properties for the purpose of performing quality measurements. Getting acquainted with the properties and limitations of measuring transducers (sensors). Calculation of the measurement uncertainty of the result.
Requirements for applicants	
Programme level learning outcomes with course contribution	
Expected course level learning outcomes (4-10 outcomes)	Know how to calculate the statistical parameters of measurement results, calculate the error of measurements. Analyze measurement system properties and evaluate the errors and the scale of their impact on the measurement

	result. Calculate the measurement uncertainty of simple measurement procedures.

Course contents by individual lessons	
Class	Practice
P1 Introduction to Metrology. SI system unit. Scientific, Industrial and Basic Metrology. Laboratory Accreditation. Traceability. Standards.	V1 Introduction. Rounding of the results. Total error of indirectly measured quantity.
P2 Basic concepts. Error of measurement. Total error of indirect measurement. Rounding of results. Seminar assignments.	V2 Exercise: Measurement of length and mass. Project work assignment.
P3 Statistics and application of MS Excel: Statistics and sampling. Basic statistical tools and concepts. Descriptive statistics.	V3 Statistics, examples.
P4 Statistics and Application of MS Excel: Histogram. Outliers. Regression (the least squares method). t- test for comparison of two mean values. F-test to compare two variances.	V4 Practicing statistical calculations on measurement results ..
P5 Signals. Decibels. Analog and digital signals. Static and dynamic signals. Bode's diagram. Filters. Noise. Dither. Thermovoltage.	V5 Signals: Resolution, Decibel, Frequency Bandwidth, Rise time. Virtual instrument. USB data acquisition.
P6 Measurement chain and voltage measurement: Instrumentation. Measuring chain. Characteristics of chain components, influence quantities, and total error of the measuring chain. Calculation of accuracy in the physical quantity of the transducer.	V6 Filters. Low pass and high pass. Noise. Adding of noise of the components in the measuring chain.
P7 Measurement of electrical quantities - voltage: Instrumentation based on the computer. Multiplexing. S & H. Ground loops. Input configuration of the instrument. Aliasing. Electromagnetically induced noise. Line Integration. Setling time. Internal resistance of voltmeters - correction of systematic error.	V7 Systematic measurement error due to voltmeter resistance. Use of digital multimeter, oscilloscope and DAQ card.
P8 Measurement of other electrical quantities: measurement of current by ampermeter, shunt, current transformer, terminated broadband transformer and Rogowski coil. Comparison. Resistance and Impedance Measurement: Two-wire and four-wire measurement of resistance. Measurement of input and output resistance.	V8 Measurement of current by shunt and current transformer.

P9 Measurement of nonelectric quantities: - measurement of deformation by strain gauges - measurement of temperature using thermocouple, RTD and NTC thermistor	V9 Resistance measurement errors and error correction examples. Thermoelectric voltages and their impact on the measurement results. Potentiometric divider.
P10 - Measurement of length and displacement with LVDT and extensometer - measuring pressure, force, mass - Measurement of sound, noise and vibration	V10 Measurement of deformation using strain gauges. Measurement of temperature and temperature calibration.
P11 Measurement uncertainty: distribution and uncertainty. Uncertainty of direct and indirect measurements. Resolution uncertainty. Selection of factor k. Welch-Satterthwait equation. k factor for the two dominant components of uncertainty.	V11 Calibration of LVDT. Mass balance calibration. Sound measurements.
P12 Examples of measurement uncertainty calculation, measurement uncertainty: exercise.	V12 Project Work
P13 Mobile measurement applications, demonstrations in the laboratory	V13 Project Work
P14 Demonstrations in the laboratory	V14 Project Work
P15 Demonstrations in the laboratory	V15 Project work assessment.

Students' obligations	Regular presence at the class (maximum absence 3 + 1), writen (accepted by the teacher) presentation of seminar, project work within personal deadline.			
Students' work track *(indicate share in ECTS points for each activity so that overall ECTS number corresponds to class credits score):*	Class attendance		Research	
	Project	40 %	Report	
	Colloquium		Seminar paper	10 %
	Practical work		Oral exam	40 %
	Written exam	10 %	(Extra)	
Type of exam, grades and evaluation of students work during class and on final exam	Students presents a seminar in front of other students. Project work. Oral exam.			
Mandatory literature (available in the Library and via other media)	1. Kuhinek, D.: Measurement Technology, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, 2018. 2. Morris, Alan S: Measurement and Instrumentation Principles, Elsevier, 2006. 3. Witte, R. A.: Electronic test instruments, second edition, Prentice Hall PTR, USA, 2002. 4. EA-4/02:2013: Evaluation of the uncertainty of Measurement in Calibration, European Accreditation.			

Aditional literature (at the moment of study program proposition application)	1. Webster, John G.: The Measurement, Instrumentation and Sensors Handbook, CRC Press LLC,1999. 2. Taylor, John R.: An Introduction to Error Analysis, second edition, University Science Boks, Sausalito, California, USA, 1997. 3. Northrop, R. B.: Introduction to Instrumentation and Measurements, Second Edition, Taylor and Francis, Boca Raton, 2005.
Examination terms	Every Tuesday within exam-terms (at time 10 a.m.).
Other	

Course Teacher:

Assoc. Prof. Dalibor Kuhinek PhD