Faculty of Mechanical Engineering / ENERGY EFFICIENCY / MEASUREMENT AND MEASURING SYSTEMS

Course:	MEASUREMENT AND MEASURING SYSTEMS			
Course ID	**Course status**	**Semester**	**ECTS credits**	**Lessons** (Lessons+Exercises+Laboratory)
12463	Mandatory	1	6	2+2+0
Programs	ENERGY EFFICIENCY			
Prerequisites	None			
Aims	Introduction to the most important methods to measure flow, temperature, and energy quantities (temperature, pressure, flow rate, energy load and consumption), the derived quantities (like heat exchanger effectiveness, the heat pump coefficient of performance "COP", etc), and becoming familiar with typical and specific HVAC equipment and the equipment for engineering measurements.			
Learning outcomes	The studient will be able to: 1. Interpret the importance of experiment ; 2.Describe the experimental instalation of a HVAC system (heating, ventilation and airconditioning) available at the Energy Lab of Mechanical Engineering Faculty; 3. Have and overview of the techniques for measuring temperature ; 4. Describe the principle of operation for thermo-electric sensing equipment (thermocuple, thermo resistors, IR camera, etc); 5. Understand and calculate the value of the time constant of a sensor / measurement system, in a Lab DAQ measurement setup; 6. Interpret and present the approach to experimentaly determine the characteristics of a orifice-type flow meter for measuring flow in a HVAC system. Conduct a experimental validation of the literature formulae to calculate the flow rate from measure differential pressure on the orifice meter differential pressure transducer. Carry out a calculation of flowrate for a given set of input data, as in real-life engineering scenario. 7. To interpret and calculate the energy flow for a HVAC system consisting of a heat pump and an airhandling unit, using the available laboratory equipment and devices; 8. Determine the properties of a fan-coil heat exchanger unit in the available HVAC system of the Lab; The water-air heat exchanger and the water-refrigerant heat exchangers. 9. Become profficient to measure basic electric quanties which determine the electric load of the machinery; 10. Calculate the coefficient of performance "COP" of a HVAC system			
Lecturer / Teaching assistant	Prof. dr Milan Šekularac, dipl.ing.mech.eng. & Prof. dr Nikola Žarić, dipl.ing.el.eng MSc Boris Hrnčić, dipl.ing.mech.eng.			
Methodology	Lecture, excercises with numerical examples and slides, laboratory classes with hands-on work			
Plan and program of work				
Preparing week	Preparation and registration of the semester			
I week lectures	General overview of the quantities of interest for measurement in the contect of energy installations for heating, cooling, airconditions and other machinery. Overview of the instrumentations and techniques for measuring temperature. Measuring flow rate, overview of the instruments and methods. Pressure measurements overview. Measuring electrical quantities (voltage, current, cos(fi)). Derived variables: heat transfer coefficient in heat exchangers for HVAC systems, evaporators and condensers effectiveness performance and sizing; cooling / heating "COP" coefficient for a HVAC system;			
I week exercises	Overview of physical properties, the instrumentation and measuring techniques, hands-on work in the Laboratory			
II week lectures	Principal components of the HVAC instalations; Operating scheme of the laboratory HVAC installation: heat pumpe KTK in the Energy Lab of the Mechanical Engineering Faculty. Overview of the scheme, the thermodynamic diagram for R407C in ln(p)-h coordinates, the layout of a typical thermodynamic cooling cycle, overview of the properties of the condenser and the evaporator heat echanger units. Performance calculation by an iterative algorithm in transient operation of the HVAC system.			
II week exercises	Design calculations for principal components of the HVAC system. Introduction to the thermodynamical cycle of the refrigerant fluid. Heat exchanger performances. Osnovni proračun komponenti sistema. Uvid u termodinamički ln(p)-i dijagram i ciklus. Karakteristike razmjenjivača			
III week lectures	Calculation of the dynamics of a HVAC system operation. Determination of the derived properties (COP).			
III week exercises	HVAC system and its components performance. An insight through experiments in the Lab.			
IV week lectures	Thermometers, thermocouples; Time constant in measuring transient processes; Temperature measurements in a moving fluid			
IV week exercises	Temperature measurements, instruments and DAQ acquisition, time consant. LabView data acqusition from a USB type DAQ card into a laptop computer. LabView setup.			
V week lectures	IR infrared camera principles of operation, use, and data processing			

V week exercises	Measurements by use of a infrared camera
VI week lectures	Flow rate measurements; Overview of the instruments and approaches: volumetric method, orifice type flow meter methods, turbine type flow meters, ultrasonic flow meters, electromagnetic flow meter. Hands on introduction and use in the Lab
VI week exercises	Introducing the use of flow measurement equipment in the Lab Air velocity and flow rate measurements in ventilation systems Pitot tube and turbine type flowmeters for air
VII week lectures	Flow rate measurements using turbine type flowmeter. The case of air in ventilation systems, and the case of water in closed hydraulic circuits in HVAC systems. Water flow rate measurements using orifice type flowmeter and a U-tube differential manometer. The orifice properties according to the literature data; Hands on verification of the orifice characteristic in the Lab; Worked out example from the engineering real-life use of determination of the flow rate through the orifice based on the measured differential pressure and a known orifice geometry, using literature data for the discharge coefficient calculation of a given orifice geometry.
VII week exercises	Flow rate measurements using orifice type flowmeter
VIII week lectures	Pressure measurements. Static, dynamic, total pressure. Pitot tube. Lab and on-site instruments. Dead weight tester for manometer calibration.
VIII week exercises	Measurements of dynamic and absolute pressure using comercial instruments
IX week lectures	Measurements of the properties of a HVAC system components: heat transfer coefficient and the exchanger effectiveness in the HVAC system - experimental insight and a design calculation using specialized literature. Performance of the fan coil units in a Laboratory HVAC system. Measurements of electrical quantities, active power. Determination of electric energy consumption and load in kW; Cooling / heating COP determination
IX week exercises	Measurements of the energy performance indicators for aHVAC system and its components, in the Lab
X week lectures	Determination of the HVAC system COP in transient operation conditions
X week exercises	Calculating the seasonal COP in HVAC systems
XI week lectures	Thermoelectric generator (TEC), main properties
XI week exercises	Experiments with the thermoelectric generator
XII week lectures	DAQ - Akvizicija i obrada signala
XII week exercises	Acqusition of the signals using LabView and signal processing in Matlab
XIII week lectures	
XIII week exercises	
XIV week lectures	
XIV week exercises	
XV week lectures	
XV week exercises	
Student workload	

Per week	**Per semester**
6 credits x 40/30=8 hours and 0 minuts 2 sat(a) theoretical classes 0 sat(a) practical classes 2 excercises **4 hour(s) i 0 minuts** of independent work, including consultations	Classes and final exam: **8 hour(s) i 0 minuts x 16 =128 hour(s) i 0 minuts** Necessary preparation before the beginning of the semester (administration, registration, certification): **8 hour(s) i 0 minuts x 2 =16 hour(s) i 0 minuts** Total workload for the subject: **6 x 30=180 hour(s)** Additional work for exam preparation in the preparing exam period, including taking the remedial exam from 0 to 30 hours (remaining time from the first two items to the total load for the item) **36 hour(s) i 0 minuts** Workload structure: **128 hour(s) i 0 minuts (cources), 16 hour(s) i 0 minuts (preparation), 36 hour(s) i 0 minuts (additional work)**
Student obligations	
Consultations	
Literature	1. Handouts; Master thesis ,,Dynamics of a HVAC system consisting of a heat pump and an air handling unit in the cooling mode of operation", M.Šekularac, 2008. 2. Publications from the HVAC equipment and the measurement - DAQ equipment producers / suppliers; Selected chapters

			from the literature related to the HVAC equipment used and the refrigerant R407C 3. Lecture slides 4. Foundations of measurement techniques, Ivo Vušković, Mašinski fakultet Beograd 5. Selected scientific papers 6. LabView tutorials			
Examination methods						
Special remarks						
Comment						
Grade:	F	E	D	C	B	A
Number of points	less than 50 points	greater than or equal to 50 points and less than 60 points	greater than or equal to 60 points and less than 70 points	greater than or equal to 70 points and less than 80 points	greater than or equal to 80 points and less than 90 points	greater than or equal to 90 points