1. GENERAL INFORMATION			
1.1. Course teacher	Prof. Dražan Jozić, PhD Assitant Prof. Sanja Perinović Jozić, PhD	1.6. Year of the study	1st year (2nd semester)
1.2. Name of the course	Methods for Advanced Material Characterization	1.7. ECTS credits	5
1.3. Associate teachers		1.8. Type of instruction (number of hours L + E + S + e-learning)	Total: 60 (L:30, E30,S:0)
1.4. Study programme (undergraduate, graduate, integrated)	Graduate	1.9. Expected enrolment in the course	10
1.5. Status of the course	☐ mandatory ☒ elective	1.10. Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	2

2. COUSE DESCRIPTION	
2.1. Course objectives	Acquisition of theoretical knowledge about different techniques and methods for characterization of materials, and practical knowledge about the preparation of samples and the application of simple and advanced instrumental techniques and methods.
2.2. Enrolment requirements and/or entry competences required for the course	
2.3. Learning outcomes at the level of the programme to which the course contributes	• Utilise advanced laboratory procedures and instruments for synthesis of new products, create sustainable processes, and solve problems of water, air and soil pollution. • Apply different analytical techniques, analytical and numerical methods, as well as software tools in creative problem solving of engineering challenges, proposing sustainable technological solutions. • Create a critical analysis, evaluation and interpretation of personal results, and compare them with existing data in scientific and expert literature • Outline results of independent and teamwork in a written and oral form to non-experts and experts in a clear and coherent way.
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	1. optimally use numerous possibilities of individual instruments 2. conclude which instrumental technique and method can be applied to determine predicted properties of materials 3. properly prepare samples and adjust a instrument for a particular measurement, i.e. to calibrate the instrument 4. independently carry out measurements and determine basic parameters of the measured data
2.5. Course content (syllabus)	**WEEK 1.** Introductory notes related to the course. Development of techniques and methods for characterization of materials throughout the history. Introduction to methods for characterization of materials. The accuracy and precision of measurement, statistical deviation of measurement. Basic terminology in instrumental characterization of materials (calibration, recalibration, baseline, standards, systematic errors..).

	WEEK 2. Physical and chemical properties of materials. Basic notations and terminology. Crystal states. Symmetry elements. Crystal systems. Spatial symmetry and space groups. Crystal planes, Miller indices and interplane distances. d. **WEEK 3.** Isomorphism and polymorphism. Enantiomorphism and chirality. Crystal habits. Dendrites. Composite crystals and splicings. Irregularities in crystals. Electromagnetic radiation. Instrumental methods and techniques. X-ray radiation. **WEEK 4.** The interaction of X-ray radiation with electrons. The interaction of electromagnetic radiation with atoms. Determination of the basic parameters of the diffraction pattern. Industrial constructions of instrument and performance limitations. **WEEK 5.** Basics of X-ray fluorescence techniques and methods. Calibration and calibration standards of instruments. Interpretation of the results. **WEEK 6.** Microscopic techniques. Light microscopy. The law of reflection. The law of refraction. Absolute and relative refractive index. Methods of measuring the refractive index. Birefringence. Construction of microscope. Polarizing microscope. Compensation plates and their role. **WEEK 7.** Partial exam. **WEEK 8.** Basics interactions of infrared radiation with a matter. Important terminology related to infrared spectroscopy and its possible application. Methods for a sample preparation. Methods and techniques of measurement. Practical guidelines for the measurement on infrared spectrometer. **WEEK 9.** Introduction to thermal techniques and methods. Fundamental terminology. Types of thermal techniques and methods. Factors affecting the results of thermal analysis. **WEEK 10.** Theoretical background of thermogravimetry (TG). Standards for calibration and calibration methods of thermogravimeter and thermogravimeter / differential thermal analyzer (TG/DTA). Determination of the baseline and measurement interpretation. Importance of instrument calibration, measurement program, working conditions, preparation of samples. Interpretation of thermogravimetric curves. Possible applications of thermogravimetry (examples). Mistakes that occur in measurement. **WEEK 11.** Partial exam. Theoretical background of differential scanning calorimetry (DSC) and differential thermal analysis (DTA). Instrumental designs of these techniques. **WEEK 12.** Importance of instrument calibration, measurement program, working conditions, preparation of samples for differential scanning calorimetry and differential thermal analysis. Standards for calibration and recalibration of instruments. Determination of a baseline and measurement interpretation. Possible applications (examples) and possible problems. Mistakes that occur in the measurement. **WEEK 13.** Theoretical background of thermomechanical (TMA) analysis and dynamic mechanical analysis (DMA). Construction of thermomechanical system. Calibration of the instrument, measurement program, working conditions, sample preparation, etc. Thermomechanical curves. Possible applications (examples) and possible problems. **WEEK 14.** Construction of dynamic mechanical system (DMA). Calibration of the instrument, measurement program, working conditions, sample preparation, etc. Dynamic mechanical curves. Possible applications (examples) and possible problems.

	WEEK 15. Partial exam <u>Exercises</u> Rapid methods for characterization of materials using X-ray diffraction Determination of the elemental composition using fluorescence techniques. Application of microscopy in characterization of materials. Application of infrared spectroscopy in characterization of materials. Determination of thermal and thermo-oxidative stability of materials with thermogravimetric method. Determination of thermal properties of material using differential scanning calorimetry.

2.6. Format of instruction:	☒ lectures ☐ seminars and workshops ☒ exercises ☐ online in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☐ multimedia and the internet ☒ laboratory ☐ work with mentor ☐ (other)	2.7. Comments:
2.8. Student responsibilities	Attendance of 70%-100% of lectures, and 100% of exercises		

2.9. Monitoring student work	Class attendance	YES		Research		NO	Oral exam	YES	
	Experimental work	YES		Report	YES		(other)		
	Essay		NO	Seminar paper	YES		(other)		
	Preliminary exam	YES		Practical work	YES		(other)		
	Project		NO	Written exam	YES		ECTS credits (total)	5	

	Title	**Number of copies in the library**	**Availability via other media**
2.10. Required literature (available in the library and/or via other media)	Michael E. Brown, Introduction to Thermal Analysis, Techniques and Applications (2nd edition), Kluwer Academics Publishers, New York, 2004.	1	
	B.E. Warren, X-Ray diffraction, Dover Publications, New York, 1990.	1	
	Roger N. Clark, Spectroscopy of Rocks and Minerals, and Principles of Spectroscopy, John Wiley and Sons, Inc, New York, 1999.	1	
2.11. Optional literature	Selected articles from journals recommended by the lecturer		
2.12. Other (as the proposer wishes to add)			