FORM 2

1) Course teacher: dr. sc. Miroslav Jerković, Assistant Professor

2) Name of the course: Mathematics I

3) Study programme (undergraduate, graduate): undergraduate

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Distinguish and correctly use various number structures, their notation and available operations.

2. Apply coordinate systems (plane, space and higher-dimensional) and corresponding basic mathematical constructions: vectors, matrices and systems of linear equations.

3. Use elementary functions, distinguish their graphs and be able to interpret the corresponding relationship between dependent variables.

4. Master the notion of derivative, as well its physical and geometrical interpretation. Be competent to apply the notion of derivative to model and solve practical problems.

5. Actively use the corresponding basic procedures in program packages Mathematica or Matlab.

6) Learning outcomes at the level of the study programme:

1. Apply obtained competence in using numbers for quantitative description of physical properties.

2. Use the knowledge of coordinate systems, matrices and vectors to model engeneering problems.

3. Apply functions and their derivations in analysis of engineering problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Real and complex numbers	- distinguish natural, integer, rational, real and complex numbers and their notation - calculate with real numbers, their approximate values, and learn to estimate their values - understand relations among	- for a given number, determine the number type, its value, its value and equivalent notation, as well as learn how to represent it geometrically - execute given operations

	numbers by being able to solve simple equations and inequalities - apply numbers for writing down the values of physical quantities	with numbers algebraically and numerically, exactly and approximately - determine the relation among the given numbers, set and solve a simple equation and inequality - interpret a connection among the given physical quantities, as well as among their numerical values
2. Two-dimensional, three-dimensional and n-dimensional real vector space	- define and graphically represent a coordinate system on a line, in plane and in space, as well as understand the generalization to higher dimensions - apply the notion of coordinate system to represent geometrical and physical relation between various quantities - define analitically a notion of vector in real vector space, use various equivalent notations and be able to use operations on vectors - interpret vector and its components form the engineering point of view (forces, velocity etc.)	- represent a point or a set of points, given by their coordinate values - write down the analytical expression representing a geometrical or physical relation between quantities - execute given vector operations
3. Some transformations of plane and space – the notion of matrices and linear operators	- define matrix and its elements - apply vectors and matrices to write down some basic transformations of plane and space: symmetry, projection, translation, rotation - distinguish various types of matrices: square matrix, symmetric matrix, diagonal	- determine columns, rows, elements, type and order of a given matrix - determine the matrix representation of a given transformation, or, vice versa, determine the transformation out of a given matrix representation - determine the type of a

	matrix etc.	given matrix
4. Algebra of matrices. Inverse matrix and determinant	- define operations with square matrices, be able to use these operations and compare them with number operations - define the notion of inverse matrix and its state its properties - define the matrix determinant for matrices of second and third order	- execute the given matrix operations - calculate the determinant of a given matrix of second or third order
5. Scalar, vector and mixed product of vectors	- geometrically define the angle between two vectors - define and calculate the scalar product of vectors, and establish a relationship with the notion of angle between two vectors - analitically, geometrically and physically define the vector product; learn to calculate it and use it to find the area given by two vectors - define the mixed product, calculate it and use it to find the volume determined by three vectors	- represent a relation between two vectors, regarding the angle between them - write down the formulas for scalar product of vectors and for the angle between vectors, and apply them to given vectors - write down the formulas for vector and mixed product of vectors, and apply these formulas to given vectors
6. Systems of linear equations and solution methods	- define the notion of a system of linear equations, and its set of solutions - define and apply the matrix notation for a system of linear equations - solve some simple systems by using, where appropriate, the inverse matrix method, Cramer rule or the Gauss-Jordan method - calculate the determinant	- write a matrix notation of a given linear system - solve a given system using the required, or appropriate, method - calculate the determinant and inverse of a given matrix, using elementary matrix operations

	and inverse of a square matrix, by using the elementary matrix operations	
7. Notion and geometrical meaning of eigenvalues and eigenvectors (not obligatory)	- define the notions of eigenvalue and eigenvector of a matrix - interpret geometrically and physically these two notions - determine eigenvalues and eigenvectors in concrete examples - explain the special role of symmetric matrices	- check if a given number (vector) is an eigenvalue (eigenvector) of a given matrix - determine and interpret the eigenvalues and eigenvectors of a given matrix of second order
8. Notion of function, its graph and inverse function	- present the notion of a function and interpret it as an operation and notation of a relation between dependent quantities - define the notion of a graph of function and the notion of a graph equation - state basic properties of functions and graphical interpretion of these properties - define the inverse function, its graph and sketch the connection to equation solving	- calculate the values of a given function and represent those values as points of its graph - determine the value of a given function by using its graph - interpret the properties of a function if its graph is given and vice versa, represent graphically a function with specific property - present a graphical solution of a given equation and estimate the solution graphically
9. Elementary functions. Functions important in engineering and natural sciences.	- define the notion of elementary function, give a list of elementary functions and their inverse functions - represent graphically basic elementary functions and their inverse functions (powers and roots, exponential and logarithmic functions, trigonometric and arcus functions)	- calculate the values of a given elementary function - sketch the graph of a given basic elementary function - solve a given equation (exponential, logarithmic, trigonometric etc.) exactly, as well as approximately

	- graphically interpret important properties of elementary functions (growth and decline, extremes, convexity and concavity, inflection points) - solve equations related to basic elementary functions - sketch the importance of applying elementary functions on engineering problems	
10. Notion of sequence, limit of a sequence and limit of a function	- define the notion of sequence of numbers and its series, as well as the notion of limit - approximately and exactly determine the limit of some important sequences - define and graphically represent the limit of a function - state some important limits of functions	- determine and write down the expression for the general term of a simple sequence given by its first few terms - calculate the limit of a given sequence - calculate the limit of a given function
11. Notion of derivative, its geometrical and physical meaning	- present the analytical definition of point derivative of a function, as well as its functional derivative - intepret the derivative physically (notion of velocity) - intepret the derivative geometrically (notion of inclination) - approximately determine the value of derivative by using the graph of a function - use the definition of a derivative to obtain the derivatives of some simple functions (as for power or	- using the definition of derivative, find derivatives of some basic functions, as for square root or square power - using the graphical representation, estimate the relative speed of change of one quantity, as compared to the other quantity

	root functions)	
12. Properties of derivative. Derivatives of elementary functions	- state the properties of functional derivatives and use them to calculate the derivatives - list the derivatives of basic elementary functions - calculate the derivatives of basic elementary functions (power function, exponential function, sinus and cosinus functions and their inverses)	- by using the table of derivatives, as well as the properties of the derivative operation, find the derivative of a given polynomial, a product or quotient of given elementary functions - find the derivative of a function composed out of given functions from the table of derivatives
13. Linear and quadratic approximation. Taylor series	- list and apply formulas for linear and quadratic approximation of a function - geometrically and analytically interpret linear approximation - derive the formula for the tangent line in a point of a graph of a function, and be able to interpret it geometrically - state the general formula for Taylor series of a function, and present the Taylor series for some basic elementary functions - apply Taylor series to approximately calculate values of a given function	- use the linear and quadratic approximations, as well as Taylor series, to calculate the approximate values of a given function - determine linear and quadratic approximations and the Taylor series for x0=0 for the following functions: exp(x), sin(x), cos(x), 1/(1-x)
14. Increasing and decreasing functions, convexity and concavity, inflection points and their physical meaning	- interpret increse and decrease of a function, as well as local extremes, by using the notion of first derivative, and apply this interpretation to a given problem - inetrpret convexity and concavity, as well as inflection points, by using the	- apply to a given function

	notion of second derivative, and apply this interpretation to a given problem - distinguish necessary and sufficient conditions in terms of derivatives, for a function to have a specific property stated above	
15. Qualitative analysis of a function by using a notion of derivative.	- use the competence obtained in Teaching unit 14 to some more involved functions	

FORM 2

1) Course teacher: dr. sc. Vladimir Dananić, associate professor	
2) Name of the course: Physics I	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Explaining the physical processes and phenomena 2. Analyzing and solving physical problems using mathematical skills (mathematical formulation of physical problems) 3. Graphical representation of the laws of physics 4. Interpretation of the obtained results 5. Relating the acquired knowledge in solving physical problems	**6) Learning outcomes at the level of the study programme:** 1. Ability to apply the laws of physics 2. Acquiring computational skills 3. Correlating the acquired knowledge 4. Application of scientific methods in solving problems 5. Deductive and inductive reasoning

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Kinematics	- to describe different kinds of motion through kinematic quantities (position, velocity, acceleration)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
2. Dynamics	- to interpret and apply Newton's laws and the laws of conservation of linear and angular momentum - to establish the equation of motion - to explain the relationship between different dynamic	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

	quantities (force, linear momentum, angular momentum, impulse, torque) - to recognize some fundamental forces in nature (Gravity)	
3. Work and Energy	- to explain the relationship between work, potential and kinetic energy - to interpret and apply the law of conservation of energy - to derive the potential energy for some conservative forces with their grafical representation	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
4. Oscillations and Waves	- to describe simple harmonic motion and apply its equiation to different periodic motions in nature -to describe different kinds of waves by means of characteristic quantities (wavelength, period, frequency, angular frequency, amplitude)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
5. Heat and Temperature	- to explain relationship between different thermodinamic quantities (heat, temperature, pressure, volume, internal energy, entropy) through thermodynamical and statistical approach. - to derive the work done in different thermodynamic processes	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

FORM 2

1) Course teacher: Svjetlana Krištafor (Assistant Professor), Ivana Steinberg (Assistant Professor)

2) Name of the course: General Chemistry

3) Study programme (undergraduate, graduate): Undergraduate

4) Status of the course: Basic

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To apply acquired knowledge that is necessary for understanding other branches of chemistry. 2. To solve chemical problems based on fundamental chemical principles. 3. To demonstrate basic laboratory skills in handling chemical substances. 4. To analyse the structure of three different states of matter. 5. To argue the properties of individual elements with respect to the position of an element in the periodic table.	1. Knowledge and understanding of scientific principles underlying material science and engineering, especially in chemistry. 2. Knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials. 3. Recognition of the need for further learning. 4. Chemical and physical laboratory skills, use of laboratory equipment and implementation of good laboratory safety practice. 5. Ability to analyse materials using chemical and physical techniques and various instrumental methods of analysis. 6. Ability to identify, formulate and solve material science and engineering problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to chemistry; Quantum world; Quantum mechanics.	The student will list the properties of matter and distinguish elements from compounds, pure substances from mixtures of substances. According to the modern theory of the atomic structure, the student will	- to identify the property as a chemical or physical, intensive or extensive - to distinguish molecules, atoms and ions - to describe the structure of atoms - to write the electronic

	explain the uncertainty principle of quantum mechanics and outline the energy levels and forms of atomic orbitals. Based on the absorption and emission of electromagnetic radiation student will compare the ground and excited states of atoms.	configuration of neutral atoms and ions
2. Chemical bonds; Molecular shape and structure;	The student will distinguish covalent and ionic chemical bonds and give examples of covalent and ionic compounds. The student will define the valence and core electrons from the position of the element in periodic table. The student will write Lewis symbols of elements and apply them when drawing Lewis structures. Based on the quantum theory of chemical bonding, the student will sketch the energy levels of the molecules, write electronic configuration of molecules and estimate the molecular (non)stability.	- to draw the Lewis structures of molecules and ions - to determine the dipole character and bonding (ionic or covalent) based on the electronegativity of elements - to predict the type, length and strength of chemical bonds - to distinguish the hybridization types and explain the difference between sigma and pi bonds
3. Gases, liquids and solids; Reaction thermodynamics; Physical and chemical equilibria.	The student will explain the difference between ideal and real gases and compare different states of matter based on the intermolecular interaction. The student will also explain the role of enthalpy in a chemical reaction, estimate (non)spontaneity of the process, determine the speed and order of chemical	- to calculate p, V, n or T at defined conditions using gas laws - to outline and explain the types of intermolecular interactions - to calculate the change in enthalpy and Gibbs free energy of a chemical reaction - to calculate and analyze the chemical equilibrium constant - to calculate the pH of the

	reaction and estimate its direction. The student will compare the acids and bases.	solution
Electrochemistry; Coordination compounds – electronic structure and properties of complexes; Chemical kinetics; Nuclear chemistry.	The student will describe and identify reactions in electrochemical cells and to determine their (non) spontaneity. The student will determine the rate constant and order of chemical reaction. The student will also define the influence of the catalyst on the speed and direction of chemical reaction. The student will connect the temperature dependence of the speed of chemical reaction. The student will analyse the different types of radioactive decay and determine the energy changes that accompany nuclear reactions.	- to balance the redox reaction chemical equations - to calculate the potential of electrochemical cell - to calculate the rate constant of a chemical reaction based on its activation energy - to write and balance the nuclear reaction equation - to calculate the energy changes during nuclear reactions

FORM 2

1) Course teacher: Marinko Markić

2) Name of the course: Computer Programming and Application

3) Study programme (undergraduate, graduate):undergraduate

4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Solving simple problems applying Matlab software package 2. Solve simple programming problems using structured programming 3. Identify and explain numerical method for: solving nonlinear algebraic equations, numerical integration, solving ordinary differential equitation 4. Apply numerical method for: solving nonlinear algebraic equations, integration, solving ordinary differential equitation 5. Recognition of the possibilities of scientific resources on the Internet	1. The ability to identify, define and solve simple chemical engineering problems 2. The ability to choose and apply appropriate mathematical numerical methods for problem solving 3.The skill to perform mathematical calculations, including error analysis and application of corresponding criteria for acceptability assessment of the results and applied models, 4.The ability to apply basic information and communication technologies

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Programming Basic	- Explain the concept and basic properties of the algorithm - Apply an algorithm flow chart - Identify the program development phase - Apply standard algorithms for: computing the mean numbers, search the smallest and the largest among the numbers, working with natural numbers (addition,	- Apply the principles of structured programming for the development of standard algorithms - Draw a flow chart of the developed algorithm-

	multiplication, computing factorial, divisibility number with the default number), replace the contents of variables, sorting array elements (Bubble sort) -	
2. Matlab Basic and Matlab programming	-- Distinguish the data types - Describe working with arrays, vectors and matrices Apply selection structures - Use data entry and printing - Write mathematical expressions with the use of arithmetic, relational and logical operator and appropriate functions, including M-functions - Apply decisions command (single, multiple if statement) - Apply repetition structures (for-end, while-end, nested) - Graphically display data - Apply commands for saving and loading data	-Define and explain the data types in Matlab, (floating point and single and double precision numbers) - Define variables in Matlab, their distribution - Describe the definition of a series of numbers in Matlab, commands linspace and logspace, - Specify commands for drawing two-dimensional graphs in Matlab and their syntax, specify commands to draw more coordinate system or system within the same graphic windows and their syntax, - Write a program in Matlab script file which includes: data entry, use variables, the assignment statement, arithmetic operations, relational and logical operators, work with arrays, vectors and matrices, application functions, command decisions, repetition, print the results, save results to the file, draw a graph,
3. Errors in Numerical Methods	-Define (specify) sources of error - Give examples of sources of errors	- Describe sources of error

	- Distinguish the sources of error	
4. Iterative Methods for Solving Nonlinear Algebraic Equations	-Describe methods of solving algebraic equations with one variable (Iterative method, Newton-Raphson, successive bisection, secant, Regula falsi) - Distinguish the methods for solving nonlinear algebraic equations - Explain the method algorithm - Compare the methods	Draw graphical representation of calculating the roots of the equation - Write algorithm methods and draw appropriate flowchart - Specify which conditions must satisfy the algebraic equation. - Compare the advantages and disadvantages of different methods
5. Numerical integration	-Describe methods for numerical integration (trapezoid rule, Simpson, Romberg) -Distinguish the methods for numerical integration - Explain the method algorithm - Compare the methods	Draw methods graphical representation - Write algorithm methods and draw appropriate flowchart - Compare the advantages and disadvantages of different methods
6. Numerical solution of ordinary differential equations	-Describe methods for the solution of ordinary linear differential equations (Taylor, Euler, Runge-Kutta) - Distinguish between methods - Explain the method algorithm on the example - Choose the appropriate numerical method to solving linear differential equations - Compare the various methods - Compare with the exact numerical solution	- Draw a methods graphical representation - Describe the method algorithm - Draw flowchart methods - Write a program in Matlab (script file) for a given differential equation and method. The differential equation is defined in a function file. Calculate relative percentage error. Draw a graph with the numerical solution, print the results on the monitor and write them to a file. - Compare the advantages

		and disadvantages of various methods
7. Scientific resources on the Internet	- Define basic concepts of data and information - Define basic concept of a database - Collect information from databases on the Internet - Evaluate the relevance of the collected data - Develop a critical attitude towards the source of the data collected	- Apply the keywords and logical operators in searching databases on the Internet - Compare the data collected from the internet with respect to their source - Argue the use of the data obtained

FORM 2

1) Course teacher: Domagoj Vrsaljko	
2) Name of the course: Mechanics of Materials	
3) Study programme (undergraduate, graduate): Undergraduate (Material Science and Engineering)	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): After the completion of obligations and passing the exam, it is expected that the students will be able to: 1. Apply the principles of mechanics of materials in mechanical construction 2. Define the causal relationship between stress and strain in the broad sense 3. Distinguish basic types of construction loads 4. Analyse two-dimensional examples of stress and strain 5. Analyse and optimize deformation and microstructural processes 6. Apply methodologies of mechanics of materials in the development of materials and products 7. Manage and plan the processes of processing and design	**6) Learning outcomes at the level of the study programme:** After the completion of obligations and passing the exam, it is expected that the students will be able to: 1. Apply knowledge and understanding of scientific principles underlying material science and engineering, especially in chemistry, physics, mathematics and chemical engineering. 2. Apply knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials 3. Apply knowledge on various kinds of materials, especially ceramics, polymers, metals and alloys. 4. Use diverse methods of communication (Engineering drawing) with the engineering community and with society at large. 5. Analyse materials using chemical and physical techniques and various instrumental methods of analysis

FORM 2

7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Engineering drawing	- Sketch orthogonal projection - Sketch freehand isometric - Analyse the technical drawing.	- In the written test demonstrate the ability of sketching.
2. Multibody system	- Sketch environmental effects, forces, geometric analysis of problems - Solve the resulting free-body diagram.	- In the written test solve the resulting free-body diagram and resulting system of equations.
3. Strength of materials	- Calculate the stress and strain in the rod due to axial load, shear, torsion and buckling - Calculate the stress and strain of beams due to bending - Design rods and brackets.	- In the written test calculate the stress and deformation of the given system - In the oral exam comment and argue the similarities and differences of elastic, viscoelastic and plastic materials. - In the oral exam compare the advantages and disadvantages of brittle and tough materials.
4. Mechanical properties of materials	- Define the concept of microstructure - Define the term creep and relaxation - Determine the character of dynamic strength and fatigue - Recommend mechanical tests to characterize the structural material.	- In the oral exam elaborate selection process for mechanical tests and structural materials.
5. The design criteria of materials and products	- Plan the processes of materials processing.	- In the oral exam elaborate the planning of materials processing.

FORM 2

1) Course teacher: prof. dr. sc. Ivica Gusić, Full Professor / dr. sc. Miroslav Jerković, Assistant Professor	
2) Name of the course: Mathematics II	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Apply indefinite integral to problems inverse to the derivative problem 2. Use definite integral to solve the problem of area and apply it in solving engineering problems 3. Adopt the notion of a function of several variables, its derivatives and integral, and apply it to study the relations among several dependent quantities 4. Use differential equations of first and second orders to solve mathematical and physical problems 5. Actively use the corresponding basic procedures in program packages Mathematica or Matlab.	**6) Learning outcomes at the level of the study programme:** 1. Apply the indefinite and definite integrals to model an engineering problem. 2. Apply the differential calculus of functions of several variables to model an engineering problem. 3. Use ordinary and partial differential equations to model an engineering problem.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Indefinite integral and computation methods.	- define the primitive function and indefinite integral of a function - show competence in using the basic properties of indefinite integral, and in applying them in calculations - apply methods of partial	- for a given elementary function determine a primitive function - check if a give function is a primitive function of a given function - introduce an appropriate substitution to a given

	integration and substitution - apply indefinite integral to solving some simple engineering problems	integral - derive the differential equation of radioactive decay and solve it by integration - derive the differential equation of the vertical shot and solve it by integration
2. The area problem – definite integral. Leibnitz-Newton formula.	- establish a connection between the problem of area under curve and the notion of definite integral - interpret geometrically and estimate the definite integral for a positive, as well as for a general function - calculate the definite integral by using the Leibnitz-Newton formula - sketch and geometrically interpret the properties of definite integral	- represent geometrically and estimate the value of the definite integral of a given simple function - calculate the value of the definite integral of a given simple function
3. Methods for calculating the definite integral. Improper integral.	- derive and apply the formula for partial integration of the definite integral - derive and apply the formula for integration by substitution of the definite integral - define and represent graphically the improper integral - calculate the given improper integral	- using the method of partial integration, calculate the appropriate definite integral - using the method of substitution, calculate the appropriate definite integral - calculate and represent graphically the improper integral of a given function
4. Geometric application of definite integral.	- use the definite integral to calculate the area of plane domain - derive and apply the formula for volume of the rotational body	- represent graphically, estimate and calculate the area of a plane domain bounded by given curves - calculate the volume of a ball

		- calculate the volume of a cone
5. Application of definite integral to natural sciences.	- apply the definite integral to calculate the mass, barycentre and moment of inertia of a nonhomogeneous line segment with a given mass density function - explain above formulas - use the definite integral to interpret the problem of a work of a line force	- calculate the mass of a nonhomogeneous segment with a given mass density function - estimate and calculate the barycentre of a nonhomogeneous segment with a given mass density function; interpret the result - calculate the moment of inertia for a nonhomogeneous segment with a given mass density function - calculate the work of a line force given by F(x)=-kx; interpret the result
6. Notion of a function of two variables, its graph and partial derivatives.	- define a function of two variables and apply it to the problem of a relation among three dependent quantities - determine the domain of a function of two variables, and evaluate it - define and calculate the partial derivatives of first and second order for a function of two variables - physically and geometrically interpret the first order partial derivatives at a given point of a function of two variables	- determine the natural domain of a given function of two variables - determine partial derivatives and partial derivatives at a particular point for a given function of two variables
7. Linear and quadratic approximation of a function of several variables.	- write down the formula for linear approximation of a function of two variables and comment on analogy with the case of single variable - apply linear approximation to calculate the approximate	- determine linear and quadratic approximation for a given function of two variables - determine the increment and approximate increment for a given function of two

	values - write down the formulas for increment and approximate increment of a function of two variables and comment on analogy with the case of single variable - apply the formula for the approximate increment of a function - write down and apply the formula for quadratic approximation of a function of two variables	variables
8. Local extremes of a function of several variables.	- define the local extremes for a function of two variables and comment on analogy with single variable case - state and explain the necessary conditions for local extremes - apply the above criterion, by using partial derivatives of first and second order - apply the above criterion to solve some mathematical and engineering problems (the minimization problem)	- determine the local extremes for a given function of two variables - apply the local extreme criterion to solve a given minimization problem
9. Multiple integrals – consecutive integration.	- define the notion of definite integral for a positive function of two variables along the plane domain, and interpret it as a volume - by using the formula for consecutive integration, calculate the definite integral on the given domain - define and calculate the definite integral of a general function	- represent graphically the integral of a given positive function of two variables - calculate the integral of a given function of two variables, over a given plane domain - introduce the appropriate polar substitution in a given integral

	- apply polar coordinates to calculate the definite integral of a function of two variables.	
10. Application of the multiple integral.	- interpret the distribution of mass for a nonhomogeneous plane domain using the mass density function - sketch the derivation of the formula for the mass of a nonhomogeneous plane domain using its mass density function - apply formulas for determining the mass and barycentre of a nonhomogeneous plane domain	- calculate the mass of a given nonhomogeneous plane domain - estimate and calculate the barycentre of a given nonhomogeneous plane domain
11. The notion of ordinary differential equation, integral curve and initial conditions.	- state the general form of ordinary differential equations of first and second order - define the general and particular solutions - solve some simple differential equations and graphically represent the solution via integral curves - define initial conditions and their role	- determine the order of a given differential equation - check if a given function represents a solution of a given differential equation - find and represent graphically the general solution of a given simple differential equation
12. Application of ordinary differential equations. Cauchy's problem.	- state and solve the Cauchy problems of first and second order and interpret them physically	- derive and solve the Cacuhy problem of cooling (heating) - derive and solve the Cauchy problem of linear motion with constant force applied - derive the Cauchy problem of a oscillation of a particle along a line
13. Methods for solving some types of first and second	- apply the method of	- solve a given differential equation of first or second

order ordinary differential equations.	variable separation - state and solve homogeneous and nonhomogeneous linear differential equation of first order - state and solve homogeneous and nonhomogeneous linear differential equation of second order with constant coefficients	order - solve the Cauchy problem of a oscillation of a particle along a line; interpret the solution
14. The notion of partial differential equation, its solution and initial and boundary conditions.	- state the general form of partial differential equations of first and second order - define and physically interpret initial and boundary conditions	
15. Application of partial differential equations (not obligatory).	- state the differential equations for vibration of a string and heat conduction, together with the corresponding initial and boundary conditions	

FORM 2

1) Course teacher: dr. sc. Vladimir Dananić, associate professor

2) Name of the course: Physics II

3) Study programme (undergraduate, graduate): undergraduate

4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Explaining the physical processes and phenomena 2. Analyzing and solving physical problems using mathematical skills (mathematical formulation of physical problems) 3. Graphical representation of the laws of physics 4. Interpretation of the obtained results 5. Relating the acquired knowledge in solving physical problems …..	1. Ability to apply the lows of physics 2. Acquiring computational skills 3. Correlating the acquired knowledge 4. Application of scientific methods in solving problems 5. Deductive and inductive reasoning …..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Electrostatics	- to describe different kinds of electric phenomena and interactions through electrostatic quantities (charge, Coulomb force, electrostatic energy, potential and voltage, electric current)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
2. Magnetostatics	- to explain the origin of magnetic phenomena and interactions and to establish the conections between different quantities (magnetic field, electric current, Lorentz	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

FORM 2

	force)	
3. Alternating electric and magnetic fields	- to explain the relationship between alternating electric and magnetic fields - to describe the applications (alternating current, electromagnetic waves)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
4. Optics	- to explain and apply the laws of geometric and wave optics to different optical instruments (mirrors, lenses, gratings)	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions
5. Fundamental principles of quantum physics	- to explain differences between classical and quantum quantities - to apply quantum mechanical description to some phenomena in micro world	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

FORM 2

1) Course teacher: prof. dr. sc. Sandra Babić

2) Name of the course: Chemical analysis of materials

3) Study programme (graduate): Material Science and Engineering

4) Status of the course: core

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Ability to explain systematic approach to chemical analysis.

Ability to a. Apply chemical lows in identification, separation and quantification of analytes in real samples.

3. Ability to explain sampling procedure for different materials.

4. Ability to explain and apply quantitative chemical analysis.

5. Ability to explain and apply separation and isolation methods.

6. Ability to analyze and interpret the results of chemical analysis.

7. Ability to explain and apply rules of safety laboratory work and good laboratory practice (GLP).

6) Learning outcomes at the level of the study programme:

1. Knowledge and understanding of scientific principles underlying material science and engineering, especially in chemistry, physics, mathematics and chemical engineering.

2. Ability to analyze materials using chemical and physical techniques and various instrumental methods of analysis.

3. Ability to apply the acquired knowledge in materials production processes and quality control.

4. Ability to select and apply appropriate analytical methods and equipment for materials production and performance control and to analyze the results critically.

5. Ability to identify, formulate and solve material science and engineering problems.

6. Chemical and physical laboratory skills, use of laboratory equipment and implementation of good laboratory safety practice.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Systematic approach to chemical analysis	- explain systematic approach to chemical analysis	- describe the analytical process - define analyte, analytical signal and analytical information

2. Chemical lows in separation and identification methods	- apply chemical lows in identification, separation and quantification of analytes in real samples	- describe chemical reaction and chemical equilibrium - apply Le Chatelier`s principle - define constants of chemical equilibrium
3. Sample and sampling	- explain sampling procedure for different materials	- define unit, composite and laboratory sample - explain sub-sampling - describe appropriate sampling procedure for different materials
4. Quantitative chemical analysis	- apply chemical lows in identification, separation and quantification of analytes in real samples - define and discus quantitative chemical analysis	- explain gravimetric analysis - define type of precipitates - explain the mechanism of precipitation - define factors influencing formation of precipitate - define impurities in precipitates - explain titrimetric analysis - define standard solution - distinguish between primary and secondary standards - define indicator - define titration curve - explain acid-base titration - explain precipitation titration - explain complexometric titration - explain redox titration - explain potentiometric titration - explain UV-Vis absorption spectroscopy

		- explain and apply Beer`s low - ability to apply appropriate quantitative chemical method
5. Separation and isolation methods	- apply chemical lows in identification, separation and quantification of analytes in real samples - define and discus separation and isolation methods	- explain application of separation techniques - list the separation procedures - describe basic mechanisms of separation techniques (selective precipitation, electrogravimetry, liquid-liquid extraction, chromatography)
6. Statistical data analysis	- analyze and interpret results of chemical analysis	- explain systematic, random and gross errors - explain different error sources - define accuracy and precision - apply statistical tests (Q-test, t-teat and F-test) - explain and apply calibration using internal standard - define measurement uncertainty
7. Laboratory exercises	- apply chemical lows in identification, separation and quantification of analytes in real samples - apply quantitative chemical analysis - apply separation and isolation methods - explain and apply rules of safety laboratory work and good laboratory practice (GLP).	- apply chemical analysis - apply separation and isolation of analytes from real sample - use basic laboratory instrumentations - ability to properly read measurement data - writing laboratory notes - apply the GLP principles

FORM 2

1) Course teacher: Associate prof. dr. sc. Stjepan Milardovic,

2) Name of the course: Inorganic Chemistry

3) Study programme (undergraduate, graduate):Undergraduate (Chemistry and Material Engineering)

4) Status of the course: Basic

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
It is expected that the student will be able: 1. From electronic configuration to recognize stable and less stable oxidation states in the different groups of elements. 2. Used the information of standard reduction potential for prediction atoms stability in ground state. 3. Recognize the stability of hydrides and oxides using the information of atoms electronegativity 4. Make conclusion about chemical reactivity of atoms in ground state based on ionization energy data …..	1. Students have using knowledge and skills gained during the courses for problem solving in the field of chemical technology 2. The knowledge and skills gained during the courses can be used for problem solving in the field of science. 3. Applied the knowledge and skills gained during the courses as a base for additional studying. 4. The knowledge gained during the courses can be good base for the lifetime education. …..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The low of chemical periodicity and periodic table. Periodic trends in physical and chemical properties along the periods and along the groups. Periodicity of chemical properties (electronegativity, ionization energy, electron affinity,	After the course students will be able to: -explain the periodic trends in first ionization energy, electronegativity and atomic radii for the elements from H to Rn -use the information about standard reduction potentials	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

oxidation numbers, standard-state reduction potential), periodic trends in physical properties (melting point, boiling points, etc.)	for prediction oxidation and reduction trends across a row and periods -explained the periodic trends in physical properties for the elements across a row and the periods	
2. Hydrogen The general atomic and physical properties of molecular hydrogen, preparation in industrial and laboratory scale. Ionized form of hydrogen (ionic hydrides, covalent hydrides, polymeric and intermediate hydrides). The hydrogen bond and hydrogen isotopes.	After the course students will be able to -compare reactivity of atomic and molecular hydrogen -use the information about standard reduction potentials of metals for hydrogen preparation from water or from aqueous solution of acid and bases. -predict the boiling points of hydrides (13th, 14 th, 15th, 16th and 17th groups of the elements) and explain the boiling points change inside the group of the elements. -analyze the difference in boiling and melting points	-Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
3.The elements of 18th group (noble gases) Atomic and physical properties of the elements. Preparation production and use.Compounds of xenon and compounds of other noble gases, polymeric and intermediate hydrides). The hydrogen bond and hydrogen isotopes.	After the course students will be able to -recognize stable and less stable oxidation state from electron configuration of the elements -explain oxidation properties of XF2 and recognize potential oxidation state from electron configuration of xenon	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
4.The elements of 17th group (the halogens)	After the course students will be able -to recognize stable and less	Students answers the question based on application of theoretical principles

The general chemical properties of the halogens group of elements, physical and chemical trends along the group, the change of electronegativity along the group, properties of compound concerning oxidation numbers in the range :-1, 0, +1, +3, +4, +5, +7. Chemical reactivity of diatomic halogens, preparation and properties of hydrogen halides. Psudohalogens, preparation and properties. Oxoacid and oxoacid salts (preparation and properties).	stable oxidation state from electron configuration of halogens -analyze stability and bond order in two atomic halogens molecules using MO diagram -to conclude about strength of hydrohalous and hypohalous acid based on electronegativity difference between hydrogen and halogens -draw the Lewis structures of halogen oxo acid to predict the strength of acid	application Students solve the worked examples applying theoretical knowledge
5. The elements of 16th group (chalcogens) The general chemical properties of the chalcogens group of the elements. The properties of compounds concerning oxidation numbers in the range –2, –1, 0, +2, +3, +4,+6. Chemical properties and preparation of dioxygen (O2) ozone (O3) and atomic oxygen (O). The properties of oxygen compounds concerning negative oxidation state (O2-), (O22-),(O2-), (O3-) and positive oxidation state (O2+). Physical properties and structure of water, oxoacids of sulphur, selenium and tellurium, thioacids. Redox properties along the group	After the course students will be able to - to recognize stable and less stable oxidation state from electron configuration of chalcogens - to conclude about stability of hydro (oxides, sulfide, selenides and tellurides) based on electronegativity difference between hydrogen and chalcogens -conclude about bond order and magnetic properties of oxygen, oxide, peroxides and superoxides using MO diagram -conclude about molecular and atomic oxygen reactivity based on reaction entalphy -analyze acid-base and redox properties of oxygen compouns (oxidation state -2 to 0)	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

FORM 2

6. The elements of 15th group (nitrogen group of the elements) The general chemical properties of the nitrogen group of the elements. The change of electronegativity along the group, properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +3, +5. Preparation and chemical properties of ammonia and ammonium salts, nitric acid, hydrazine, nitrogen oxides (N2O, NO, NO2, N2O3, N2O5) and oxoacid of nitrogen. Preparation, use and chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth.	After the course students will be able to - recognize stable and less stable oxidation state from electron configuration of 15th group of elements -conclude about stability of hydrides and oxides of 15 the group of elements by using data about electronegativity -analyzed redox properties of elements (15th group) in ground state using information about standard reduction potentials -conclude about reactivity of elements in ground state using data about ionization energy - explain preparation acid-base and redox properties of ammonia -compare reactivity, stability acid base and redox properties of ammonia, phosphine, arsine and bismuthine -conclude about bond order of N2O, NO, NO2, N2O3, N2O5 using MO diagram for nitrogen and oxygen - compare acid strength for oxo acid of 15th group of element oxidation state +3 and +5	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
7. The 14th group of the elements (carbon group)	After the course students will be able to	Students answers the question based on application

The general chemical properties of the carbon group of the elements. Preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO2. Chemical properties of the carbon (negative oxidation state) compounds (carbides) and silicon (silicides). Chemical properties, preparation and use of silicates and silicon. Chemical and physical properties of germanium tin and lead compounds of positive oxidation state (+2, +4). Lead battery.	- recognize stable and less stable oxidation state from electron configuration of 14th group of elements -conclude about stability of hydrides and oxides of 14 th group of elements by using data about electronegativity -analyzed redox properties of elements (14th group) in ground state using information about standard reduction potentials -conclude about reactivity of elements in ground state using data about ionization energy -analyze properties of compounds containing the elements in oxidation state -4,-2 and 0 -explain hydrolysis of tin and lead compounds -explain the preparation of silicates by condensation of $Si(OH)_4$ -prepare the silicon of desired length of Si chain	of theoretical principles Students solve the worked examples applying theoretical knowledge
8. The 13th group of the elements (boron group) The general chemical properties of the boron group of the elements. Properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +2, +3. Preparation, use and chemical properties of boric acid.	After the course students will be able to - recognize stable and less stable oxidation state from electron configuration of 13th group of elements -conclude about stability of hydrides and oxides of 13 th group of elements by using data about electronegativity	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

Preparation, use and chemical properties of aluminum, aluminum trihalides, amphoteric properties of aluminum and aluminum passivity. Chemical properties of indium and gallium compounds.	-analyzed redox properties of elements (13th group) in ground state using information about standard reduction potentials -explain the reactivity of aluminum in ground state -compare the chemistry of silicides, carbides and borides and also silanes and boranes -explain the preparation of polyborates by condensation of B(OH)3	
9.The 2nd group of the elements (alkaline earth metals) Chemical reactivity and trends of chemical and physical properties along the group. Introduction to hydrides, oxides, oxoacides, hydroxides and organometallic compounds	After the course students will be able to -conclude about reactivity of elements in ground state using data about ionization energy -explain typical reaction of alkaline earth elements -	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
10. The 1st group of the elements (alkali metals) Chemical reactivity and trends of chemical and physical properties along the group. Introduction to hydrides, peroxides, superoxides, hydroxides and organometallic compounds. Preparation of NaOH, NaHCO3, NaCl and gypsum.	After the course students will be able to conclude about - reactivity of elements in ground state using data about ionization energy -explain typical reaction of alkaline elements	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
11. Preparation and properties of metals	After the course students will be able to -explain periodic trends in group of 3d, 4d, 5d.	Students answers the question based on application of theoretical principles Students solve the worked

	-compared stability of complex for 3d, 4d and 5d elements -quantitative analyze of electron absorption spectra for various d^n system - describe magnetic properties of complex compounds and color of metals	examples applying theoretical knowledge
12. Chemical reactivity and trends of chemical and physical properties along the group of the lanthanides and actinides. The general properties of the elements of the 4th and 5th group of the elements, oxides, sulphides, oxoanions and complexes of titanium, zirconium and hafnium.	After the course students will be able to -use electronegativity data for make conclusion about hydrides, sulphides and oxides stability -write the electronic configuration of elements end conclude about possible oxidation states - -	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
13. Chemical reactivity and trends of chemical and physical properties along the d-group of elements (vanadium, chromium and manganese). Oxides and the most important compounds (oxidation states 2, 3, 4, 5 and 6).	After the course students will be able to - write the electronic configuration of elements end conclude about possible oxidation states - explain the stability and pH equilibrium of chromate and dichromate -write the Lewis structure for chromate and dichromate and explain the geometrical shape -explain the preparation of Cr 3+ compounds based on amphoteric properties of	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

	Cr_2O_3 -explain the properties of MnO_2 in acidic and base medium	
14. Chemical reactivity and trends of chemical and physical properties along the d-group of elements (iron, cobalt and nickel) and 8th, 9th and 10th group of elements. Oxides, oxyanions, complexes.	After the course students will be able to - write the electronic configuration of elements end conclude about possible oxidation states - conclude about solubility of metals in acidic solution -explain the properties of Fe^{2+} and Fe^{3+}hexacyano complexes -explain the properties of Co^{2+} and Co^{3+} complexes	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge
15. Chemical reactivity and trends of chemical and physical properties along the d-group of copper and zinc (11th and 12th group of elements). Oxides, oxyanions, complexes, biochemistry of copper.	After the course students will be able to -write the electronic configuration of elements end conclude about possible oxidation states -explain the stability of Cu^{2+} and Au^{3+} compounds -explain oxidation of gold and silver by oxygen and explain importance of formation of cyano complexes	Students answers the question based on application of theoretical principles Students solve the worked examples applying theoretical knowledge

FORM 2

English language (basic course) 1st semester

COURSE AIM: Gaining competences like reading, oral and written fluency in the English language related to chemistry. Individual classification of new vocabulary by using the on-line dictionaries to acquire correct pronunciation and placing it in the e-class glossary. As part of the course students will infer basic vocabulary of chemical terminology in English, adjectives that describe the various states of matter, compounds and solutions, and ways in which they can read chemical equations, rules when to use the definite article and the indefinite articles. The students will also demonstrate the rules pertaining to the order of adjectives in a sentence, the comparison of adjectives and superlative form of adjectives and adverbs. They will also illustrate how to write a CV, do the revision tests on their own in the e-class, take part in group work and put their group work in the e-portfolio.
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF THE STUDENTS:
General competencies: pronunciation of basic chemistry elements and names of compounds, acids, molecules and reading of numbers, equations as well as naming the ionic compounds in English.
Specific competencies: describing the characteristics of a material by using adjectives, use of suffixes and prefixes, comparison of adjectives, adverbs and linking words.
STUDENT OBLIGATIONS: The students are obliged to attend classes and are to put their CV in their e-portfolio (Euro pass CV). They are obliged to practice solving the revision tests to prepare for the midterm tests. They become eligible to attend the midterm tests by attending class regularly. Students must have their indexes or ID cards in order to take part in written tests. If they are not eligible to attend the midterm tests then they have to take the final written and oral tests at the end of the second semester. The oral test refers to the lab experiment they did as a group which should be in their e-portfolio. They have to orally explain the lab report in order to get a final grade.
SIGNATURE REQUIREMENTS: The students must attend 80 percent of all classes and take part in the language exercises during class, write their CV (Euro pass CV) and put their group work and CV in the e-portfolio. They are to pass the revision tests in the e-class on their own. They have to pass all written and oral exams for the final grade.
TEACHING METHOD: lectures, individual work on the e-class and e-portfolio, language exercises such as reading, pronunciation, answering questions, pair work, group work, use of computer and consultations according to necessity.
METHOD OF ASSESSMENT:
Written midterm tests (60 percent or more on both midterm tests) and e-portfolio content
Written final exam (minimum 60 percent to pass) and oral exam (presentation of lab experiment conducted at the University and filmed) which is linked to the filmed lab experiment group work in their e-portfolio.
QUALITY CONTROL AND SUCCESS OF COURSE: anonymous student survey
METHOD PREREQUISITES:
Access to a computer and knowledge of e-class and e-portfolio passwords in the Moodle and Merlin programs.
COURSE LEARNING OUTCOMES:
1 students will generate basic concepts of chemistry terminology in English
2 students will explain new vocabulary and demonstrate pronunciation of it by learning it on

their own with the aid of on-line dictionaries

3 students will demonstrate how to use the e-portfolio at the beginners level

4 students will examine the additional materials in the e-class

5 students will prepare for the midterm tests by practicing the revision tests in the e-class

PROGRAM LEARNING OUTCOMES:

1 students will interpret the expert terminology used in the field of chemistry today

2 students will generate use of English grammar at the beginners level

3 students will write their own Euro pass CV in English and put it in their e-portfolio

4 students will use the e-class and e-portfolio programs on their own

FORM 2

English language (advanced course) 1st semester

COURSE AIM: To gain competencies for advanced reading, oral and written correspondence in the English professional language of the students trait. Independent learning of new vocabulary by using the on line dictionaries that also provide US and UK pronunciation. The students will know how to apply basic technical terminology and learn to negotiate in English. Preparing the students for oral presentations in English for future international conferences. Students will have mastered the basic technical terminology in English during this course. Students will also become familiar with some of the customs of the United States and the United Kingdom.

THE DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:

General competencies: pronunciation of specific terminology that is related to various branches of technology in English.

Specific competencies: writing their own CV and seminar paper. Correct use of grammar.

STUDENT OBLIGATIONS: Students are required to attend lectures and are obliged to place their Euro pass CV in their e-portfolio. They are also expected to solve the revision tests in their e-class. They have to attend the midterm tests if they are eligible to do so, depending on their attendance record. They are obliged to bring their Index or ID card to class during midterm and final tests.

SIGNATURE ELIGABILITY: In order to get a signature at the end of each semester the student must be present in class for 80 percent of the lectures and take part in the exercises during class, write their CV and correct it, place their CV in their E-portfolio.

The student must pass midterm exam 1.

MANNER OF TEACHING: lectures, language exercises (reading, pronunciation, understanding, speaking), independent learning (e-class), pair work, group work, individual answering questions related to the subject matter, grammar exercises and consultations if need be.

ASSESSMENT MANNER AND EXAMINATION:

Written tests (minimum of 60 percent or more scored on each midterm test excuses the student from having to take the final written and oral tests). They also have to have both seminar papers in the e-portfolio in order to get the final grade.

Written test (minimum of 60 percent in order to pass) and oral test (explanation of lab experiment)

QUALITY CONTROL AND COURSE SUCCESS: anonymous student survey

METHOD PREREQUISITES:

Access to a computer and knowledge of password to access e-class and e-portfolio in the Moodlu or Merlin programs. Each student has to have their access code to enter these programs.

LEARNING OUTCOMES OF THE COURSE:

1 students will describe basic concepts of technology and summarize the terminology in English
2 students will individually learn and be able to repeat the pronunciation of new vocabulary
3 students will practice using the e-portfolio at an advanced level

FORM 2

4 students will individually examine the additional material in the e-class
5 students will individually prepare themselves for the midterm tests by reviewing the revision tests in their e-class

LEARNING OUTCOMES AT PROGRAM LEVEL:

1 students will recognize expert terminology used in their field of technological expertise
2 students will demonstrate use of English grammar at the advanced level
3 students will demonstrate how to write a CV in English (Euro pass CV) and a lab report
4 students will practice the use of the e-portfolio and e-class programs on the computer

FORM 2

1) Course teacher: Prof. Silvana Raić-Malić, PhD	
2) Name of the course: Organic Chemistry I	
3) Study programme (undergraduate, graduate): Undergraduate	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To analyze the structure of organic compounds and define the nature of chemical bonds in organic molecules based on molecular orbital theory and hybrid atomic orbitals, 2. To define the basic types of organic reactions and explain their reaction mechanisms with the recognition of reactive intermediates in reaction, 3. To identify functional groups in molecules and define corresponding class of compounds, to apply IUPAC rules for naming of organic compounds, 4. To explain conformations of alkanes and cycloalkanes, define and name isomers, 5. To select reactions of alkanes, alkenes, alkynes, alcohols, ethers, 6. To subdivide and compare reactions in which alkyl halides, alkenes, alkynes, alcohols and ethers are involved, 7. To generate synthetic approach in preparation of target compounds.	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry and chemical engineering, 2. Ability to recognise and solve qualitative and quantitative problems using the appropriate chemical principles and theories, 3. Competence in the evaluation, interpretation and synthesis of chemical information and data, 4. Safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use, 5. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Carbon compounds and introduction to structural theory of organic chemistry	- to analyze the structure of organic compounds and define the nature of chemical bonds in organic molecules based on molecular orbital theory and hybrid atomic orbitals, - to define resonance structure, - to describe and relate sp^3-, sp^2- and sp-hybridisation in structure	- to distinguish ionic and covalent bonds of selected compounds, - to indicate bond angle of given compounds, - to define the formal charges and draw the Lewis structure of given compounds, - to draw resonance structure of

	of compounds,	compounds,
2. Introduction to organic reactions: acids and bases	- to define acids and bases, - to identify the strength of acids and bases, - to explain the relationship between structure and function of acid, - to relate heterolytic bond cleavage with corresponding intermediates which are formed in reactions,	- to recognize organic compounds as acids and base, - to apply theory of acids and bases on examples of organic compounds, - to distinguish homolytic and heterolytic bond cleavage and relate them with some examples of compounds,
3. Classes of carbon compounds, functional groups	- to differentiate functional groups in molecules and subdivide compounds according to functional groups, - to apply IUPAC rules for naming of organic compounds,	- to draw structural formula of organic compounds according to name of compound and *vice versa*, - to recognize the physical properties of compounds on the basis of their structure,
4. Alkanes – conformational analysis and introduction to synthesis	- to explain conformations of alkanes and cycloalkanes, define and create a name of isomers, - to describe conformations of alkanes and cycloalkanes, - to define energy changes and stability of alkanes,	- to draw conformations of given alkanes and cycloalkanes, - to define energetic preferable conformers, - to draw conformers using Newman projection formula and sawhorse formula,
5. Stereochemistry and chirality	- to identify and name constitutional isomers and stereoisomers, - to recognize the biological significance of chirality, - to define relative and absolute configuration (CIP system of rules), - to discriminate stereoisomers of cyclic compounds,	- to give examples of constitutional isomers and stereoisomers, - to identify chiral molecules, *meso*-compounds, define absolute configuration of compounds using CIP system of rules, - to draw steroisomers of compounds with one or more stereogenic carbons using Fischer projection formulas,
6. Ionic reactions – nucleophilic substitution reactions of alkyl halide, elimination reactions of alkyl halide	- to distinguish nucleophilic substitution reactions in relation to kinetics, mechanism of reaction and stereochemistry, - to interpret competition of substitution reactions with elimination,	- to draw structures of products formed in given examples for substitution and elimination reactions, - to illustrate by examples factors favoring S_N1 versus S_N2 reactions and E1 versus E2,

FORM 2

7. Alkenes and alkynes: synthesis and properties, the addition reaction	- to explain structure of alkenes and alkynes and list reaction for their synthesis from alkyl halides or alcohols, - to describe a mechanism of addition reaction and explain reactive intermediates formed in reaction, - to explain electrophilic addition reactions in relation to structures of substrate and various reagents,	- to discriminate and compare nucleophilic substitution and elimination reactions, - to illustrate by examples regioselectivity in elimination reactions applying Hoffman's and Zaitsev's rule and Markovnikov's rule in addition reactions, - to draw structural formula of products in reactions of alkyl halides, alcohols and alkenes along with determination of stereochemistry of reactions,
8. Radical reactions	- to define radicals reactions and relative stability of obtained radicals, - to explain multiple substitution reaction versus selectivity, - to describe radical polymerization of alkenes,	- to list an examples of radical reactions along with explanation of mechanisms of these reactions, - to distinguish stability of structurally different radicals, - to illustrate by example stereochemistry of radical reaction, - to write an example of radical polymerization,
9. Alcohols and ethers	- to explain physical properties of alcohols and ethers, - to combine different methods in the synthesis of alcohols from alkenes and carbonyl compounds, - to define reactions for preparation of ethers, - to explain the strategy of application of protecting groups, - to define reactions of alcohols and ethers.	- to illustrate by examples regioselective syntheses of alcohols from alkenes, oxidation-reduction reactions and reactions of organometallic compounds along with a mechanism for these reactions, - to choose appropriate reagents in the syntheses of alcohols and ethers, as well as in their reactions, - to create synthesis using appropriate protecting groups of alcohols, - to choose efficient methods for synthesis of selected ethers.

University of Zagreb
Faculty of Chemical
Engineering and Technology

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FORM 2

1) Course teacher: Marica Ivanković; Jelena Macan	
2) Name of the course: Physical chemistry I	
3) Study programme (undergraduate, graduate): undergraduate, Materials Science and Engineering	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To define fundamental laws of physical chemistry related to gasses, thermodynamics and phase equilibria. 2. To apply mathematics in derivation of the laws 3. To prepare and perform laboratory experiments 4. To analyze and interpret experimental results 5. To write laboratory reports	**6) Learning outcomes at the level of the study programme:** 1. To recognize the relationship between structure and properties of materials 2. To perform simple experiments with available laboratory equipments and devices 3. To apply good laboratory safety practice 4. To present research results related to their study subject (orally and in writing)

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Gases	-To describe the gases laws and sketch them in p-V-T diagrams -To derive the ideal gas law using the thermodynamic and the kinetic-molecular approach -To derive the Van der Waals equation of state of real gases -To prepare and perform the laboratory experiment: *Determination of Molecular Mass by Victor-Meyer's*	- To analyze and interpret p-V-T diagrams of ideal and real gases -To calculate the properties of ideal and real gases - To determine the molecular mass of an unknown easy volatile liquid - To explain the mathematical derivation of the equations of state

	Method - To analyze and interpret experimental results and to write laboratory report	
2. Thermodynamics	-To describe 1st, 2nd and 3rd law of thermodynamics as well as Hess's law and Kirchhoff's Law -to distinguish irreversible (spontaneous) and reversible processes -to distinguish and define heat capacities at constant pressure or volume - to distinguish and define state functions (internal energy, enthalpy, entropy , Gibbs energy) -to derive the temperature and pressure dependence of Gibbs energy -To prepare and perform the laboratory experiment: Calorimetry: Determination of the heat of reaction - To analyze and interpret experimental results and to write laboratory report	-to explain the basic terms and principles of classical thermodynamics - to calculate the changes in state functions – - to determine experimentally the heat of reaction - To explain the mathematical derivation of the dependence of Gibbs energy on pressure and temperature
3. phase equilibria	- To describe phase changes, define the phase equilibria; and sketch phase diagrams -To derive Clapeyron's and Clausius Clapeyron's equation, Rauolt's law, Henry's law, Nernst's distribution law and Van't Hoff's law of osmotic pressure -To prepare and perform the laboratory experiments: Cryoscopy, Boiling diagram,	-To analyze and interpret phase diagrams -to apply Clapeyron's and Clausius Clapeyron's equation -- to determine experimentally the freezing point depression - to construct Boiling point diagram from obtained data

FORM 2

	Nernst's distribution law -To analyze and interpret experimental results and to write laboratory report	-To define equilibrium conditions -To explain the mathematical derivations of Clapeyron's and Clausius Clapeyron's equation, Rauolt's law, Henry's law, Nernst's distribution law and Van't Hoff's law of osmotic pressure

FORM 2

1) Course teacher: Assis. Prof. Krunoslav Žižek, PhD

2) Name of the course: Transport Phenomena

3) Study programme: Undergraduate study programme Material Science and Engineering

4) Status of the course: Required

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Get acquainted with transport phenomena (momentum, heat and mass transfer), and with conservation laws they involve. 2. To define the effects of flow regime (that is hydrodynamic conditions) on heat and mass transfer. 3. To understand fundamental laws and equations at macro-scale of the phenomenon, and to apply them (regarding the mechanism) for estimation of heat and mass properties in considered hydrodynamic system. 4. To utilize the concept of transport phenomena analogy (momentum and heat transfer, momentum and mass transfer) for quantifying transport coefficients.	1. Gaining of skills for a lab work. 2. Understand techniques and methods used in an industrial-scale plant and in quality of insurance. 3. Apply methodology for theoretical interpretation of experimental data. 4. Practise fundamental knowledges regarding core engineering courses.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to transport phenomena fundamentals	- to define terms necessary for understanding and description of processes with immanent transport phenomena (momentum, heat and mass transfer)	- distinguish the mechanisms of transport phenomena - define basic equations that are descriptors for processes with occurring transport phenomena - differ Newton and non-Newton fluids and summarize model equations that are used as their descriptors
2. Momentum transfer	- to memorize and to adopt conservation laws regarding	- use conservation laws (regarding fluid flow phenomena) for estimation

	fluid flow phenomena - to define the structure and birth of hydrodynamic boundary layer - to understand fundamentals of fluid flow phenomena - to recognize characteristic cases (processes) regarding momentum transfer and to apply congruent equations	of pump power required for liquid transport in a pipeline with a complex design - define the effect of flow regime (that is hydrodynamic conditions) on the structure of boundary layer - determine flow velocity in a pipe (mainly circular tube), sketch velocity distribution and relate maximum and mean (average) flow velocity for both laminar and turbulent flow in pipes
3. Heat transfer	- to define and to differ mechanisms of heat transport /heat transfer modes (heat conduction, convection, radiation) - to use equations for stationary and non-stationary heat conduction - to define the effect of hydrodynamic conditions on heat transfer by forced convection in pipes - to summarize the concept and basic laws regarding heat transport by radiation	- explain the criterion for detection and differing mechanisms for heat transport - define driving force of the process, the area of heat exchange, the overall heat transfer coefficient and calculate heat flow regarding various process conditions (flow regimes) - detect the effect of hydrodynamic conditions on heat transfer - reveal the concept for defining of various dimensionless numbers and to adopt their meaning - explain Planck, Stefan-Boltzmann and Kirchhoff radiation laws
4. Mass transfer	- to memorize and to differ mechanisms of mass transport - to use equations for estimation of intrinsic property of a system for each	- outline usage of Fick's law of diffusion - calculate mass flow regarding various process conditions - detect the effect of

FORM 2

	mass transfer mechanism - to know methods for estimation of heat and mass transfer coefficient	hydrodynamic conditions on mass transport - apply appropriate correlations and differential equations to estimate the mass transfer coefficient
5. Analogies of transport phenomena (momentum, heat and mass transfer)	- to solve practical problems of detecting relevant heat and mass transport properties by using concept of Reynolds and Chilton-Colburn analogy	- by knowing the momentum transport (fluid flow phenomena) property estimate the heat and mass transfer properties (coefficients)

FORM 2

1) Course teacher: Associate prof. Ana Vrsalović Presečki, PhD

2) Name of the course: Mass and energy balance

3) Study programme (undergraduate, graduate): undergraduate

4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	6) Learning outcomes at the level of the study programme:
1. apply the principles of mass and energy conservation in the physical and chemical processes 2. define the process space , system boundaries , and input and output of the process 3. distinguish stationary and non-stationary as well the open and closed processes 4. set the energy and mass balance in the model systems 5. outline a simple scheme of the process of chemical and related industries	1. analyze and optimize the processes of chemical and related industries 2. apply the methodology of chemical engineering in the process development 3. manage and plan the processes 4. apply mathematical methods, models and techniques in solving case studies

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Processes and process variables	- explain the fundamental principle of mass balance. - explain the fundamental principle of energy balance. - define the measurements and measurement units - define the processes and process units - state the type of processes	- unify the measurement units for the task process - determine the type of process - determine the parameters of the process - application of differential and integral mass balance
2. Mass balance of the	- apply the principle of mass conservation on physical	- outline the process scheme, and identify the input and

physical processes	processes - define the process space, system boundaries, and input and output of the process - set the mass balance of the task examples - outline a simple scheme of the process of chemical and related industries	output flows of process - determine the basis for calculation - apply the law of mass conservation of and set the mass balances for the process - solve the system of independent linear equations
3. Mass balance of the chemical processes	- apply the principle of mass conservation on physical and chemical processes - define the process space, system boundaries, and input and output of the process - set the mass balance of the task examples - outline a simple scheme of the process of chemical and related industries	- outline the process scheme, and identify the input and output flows of process - determine the basis for calculation - apply the law of mass conservation of and set the mass balances for the process - solve the system of independent linear equations
4. Mass balance of the combustion processes	- apply the principle of mass conservation on combustion processes - define the process space, system boundaries, and input and output of the process - set the mass balance of the task examples - outline a simple scheme of the process of chemical and related industries	- outline the process scheme, and identify the input and output flows of process - determine the basis for calculation - apply the law of mass conservation of and set the mass balances for the process - solve the system of independent linear equations
5. Mass balance of physical processes performed in the multiple unit processes	- apply the principle of mass conservation on physical processes - define the process space, system boundaries, and input and output of the process - set the mass balance of the task examples	- outline the process scheme, and identify the input and output flows of process - determine the basis for calculation - apply the law of mass conservation of and set the mass balances for the process

FORM 2

	- outline a simple scheme of the process of chemical and related industries	- solve the system of independent linear equations
6. Energy balance of the processes	- apply the principle of energy conservation on physical and chemical processes - define the process space, system boundaries, and input and output of the process - define the initial and final state of the system - learn to use the thermodynamical tables in order to find the data necessary to calculate the energy balance - set the energy balance of the task examples - outline a simple scheme of the process of chemical and related industries	- outline the process scheme, and identify the input and output flows of process - determine the referent state for each component of the system - find literature data necessary to calculate the energy balance according to the initial and final state of the system and referent state - apply the law of energy conservation of and set the energy balances for the process - solve the system of independent linear equations

FORM 2

1) Course teacher: Ivica Gusić	
2) Name of the course: Numerical and Statistical Methods	
3) Study programme (undergraduate, graduate): Undergraduate	
4) Status of the course: Obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Apply principles from descriptive statistics in data analysis 2. Outline basic principles from probability theory 3. Outline and apply basic knowledge about continuous and discrete random variables. 4. Apply principles and techniques of estimations and tests in making decision about population using sample. 5. Apply procedures from programme package Excel.	**6) Learning outcomes at the level of the study programme:** 1. Apply descriptive statistics to analyse results of measurements 2. Apply probability theory to model problems in engineering 3. Apply statistics to make decision in situations from engineering

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Elements of descriptive statistics	- distinguish between population and sample - recognize and distinguish discrete and continuous statistical data - group and present statistical data - determine various data means and measures of dispersion	-- recognize in given situations the type of statistics data and sample - group given data, determine rang, frequencies and relative frequencies, arithmetic mean, mod, median, quartiles, variance and standard deviation
2. Notion of the probability, the conditional probability, the independence	-- recognize elementary events and events - calculate probability in simple situations -recognize and apply conditional probability of an event	- given an experiment, determine elementary events, describe events and calculate probability -apply independence under a suitable circumstances.

	- recognize and apply independence in successive repetition of an experiment	
3. Notion of the random variable (discrete and continuous). Expectation and variance	-define random variable and its distribution -distinguish between discrete and continuous random variable -interpret probability as the area under the graph of density function -calculate probability, expectation and variance -interpret and sketch the connection with descriptive statistics	- determine the distribution of a given random variable - given the density function, determine the function of distribution, expectation and variance
4. Binomial and Poisson distribution	-define the binomial distribution - recognize the binomial distribution and apply it in modelling engineering problems - define the Poisson distribution - recognize the Poisson distribution and apply it in modelling engineering problems	-recognize in concrete situations the binomial random variable, determine its range and distribution -apply the Poisson distribution in suitable situations
5. Exponential and Normal distribution	- define the exponential distribution and recognize it in concrete situations -apply the exponential distribution in modelling engineering problems -- define the normal distribution and recognize it in concrete situations -apply the normal distribution in modelling engineering problems - interpret and apply the three-sigma rule	-write down the density function and the distribution function of the exponential variable, and present its graphs -calculate probability of a concrete exponential distribution --write down the density function of the normal distribution and present the graph -apply the normal distribution in given situations
6. Estimation of parameters. Confidence interval.	- estimate the arithmetic mean and variance of a population by arithmetic mean and variance of a	- given a sample, estimate the arithmetic mean and variance of the population -given a sample, estimate

	sample - define confidence intervals for expectation and variance. - determine confidence intervals for expectation and variance (by using an appropriate statistical package)	confidence intervals for expectation and variance of the population
7. Basic of hypotheses testing, t-test and F-test	- outline procedures for testing hypothesis - explain the notion of the significance level -apply t-test and F-test (by using an appropriate statistical package)	-test a given hypothesis under various alternative hypothesis and various significance levels
8. Chi-square test	- describe Chi-square test - apply Chi-square test (by using an appropriate statistical package)	-sketch the procedure of Chi-square test for various distributions
9. Least square method. Correlation coefficient	- sketch the problem of adjustment of experimental data to theoretical ones - describe and apply the least square method for linear relationship - calculate the correlation coefficient	-given a statistical data, determine regression coefficients (directly and by using an appropriate statistical package) -given a statistical data, determine and comment the correlation coefficient
10. Notation of function interpolation, Lagrange and Newton interpolation polynomial, cubic spline:	- sketch the problem of interpolation of the function and its solution -explain and apply the Lagrange interpolation polynomial -explain and apply the cubic spline	- given the points, determine the corresponding Lagrange polynomial (by using an appropriate statistical package) - given the points determine the corresponding cubic spline (by using an appropriate statistical package)
11. Approximate solution of equations with one unknown	-sketch the problem of approximate solution of equations - explain and apply the tangent method -explain and apply the iteration method	-explain geometrically a given equation and its solutions -given an equation, determine approximate solution (directly and by using an appropriate statistical package)
12. Approximate solution of	-sketch the problem of	-geometrically interpret a

FORM 2

system of equations with more unknowns	approximate solution of system of equations -explain and apply the Newton method	given system of two equations - given a system of two equations, apply the Newton method
13. Optimisation (option content)	-sketch the optimisation problem	- solve a given optimisation problem
14. Approximate solution of ordinary differential equations	-graph the Cauchy problem y'=f(x,y), y(x0)=y0 and its approximate solution -explain the Euler method and the Runge-Kutta method	--graph a given Cauchy problem - given a Cauchy problem, determine the solution by using the Euler method and the Runge-Kutta method

FORM 2

1) Course teacher: **Krešimir Košutić (Full Professor)**

2) Name of the course: **Physical Chemistry II**

3) Study programme (undergraduate, graduate): **The undergraduate study of Material science and engineering**

4) Status of the course: **mandatory**

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Knowledge of the fundamental laws of physical chemistry, chemical equilibrium, surface phenomena (surface tension and adsorption), electrochemical equilibrium and chemical kinetics 2. Capacity to apply knowledge of mathematics and derive equation (which clearly describe the physical phenomenon under consideration) 3. Ability to prepare and make laboratory experiments 4. Analyze and interpret the results of experiments 5. Prepare laboratory reports	1. knowledge and understanding of scientific principles underlying material science and engineering, especially in chemistry, physics, mathematics and chemical engineering, 2. knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials 3. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work both in written and oral form 4. awareness of the impact of material science and engineering solutions on society in the social, economic and environmental context 5. chemical and physical laboratory skills, use of laboratory equipment and implementation of good laboratory safety practice 6. ability to analyze materials using chemical and physical techniques and various instrumental methods of analysis 7. ability to identify, formulate and solve material science and engineering problems

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.-2. Chemical equilibrium	- Describe the chemical equilibrium in the conditions	-Compute equilibrium constant in the examples of

	of constant pressure and temperature using the Gibbs energy, derive thermodynamic equilibrium constant - Describe the response of equilibria to temperature and pressure - Derive van't Hoff reaction isobars - Describe the homogeneous and heterogeneous chemical equilibria	homogeneous and heterogeneous equilibrium - Analyze and interpret the Haber Bosch synthesis of ammonia, optimize process parameters of pressure and temperature
3.-4. Surface phenomena: surface tension and adsorption	Describe the phenomena at the interface: solid-gas, solid-liquid and liquid-gas - Define the surface tension and derivem Gibbs adsorption isotherm - Describe and distinguish the surface-active and non-active substances -describe surface films - Define the phenomenon of adsorption and factors affecting the adsorption and adsorption equilibrium, identify the types of adsorption isotherms - Derive Langmuir isotherm - Prepare and make a 2 laboratory experiments: adsorption and surface tension - Calculate and interpret measurement data and write the Freundlich adsorption isotherm and write a lab report	-Explain importance of surfactants and their application in practice - Recognize the importance of experimental conditions determining the adsorption isotherm, - Freundlich isotherm parameters interpret - Demonstrate skill computation and application Frundlichove, Langmurove and B.E.T. isotherms
5.-9. Electrochemistry: the conductivities of electrolyte solution, equilibrium electrochemistry	- Describe conductivity of electrolytes and distinguish strong from weak electrolyte, define 1st and 2nd Kohlraush' law	- An experimental determine the conductivity of strong and weak electrolytes - An experimental determine electrode potential,

	-Derive an Ostwald's law - Define the concept of activity - Explain the Debye-Hückel theory of strong electrolytes Describe the equilibrium of electrode-solution -Derive the thermodynamic expression for the electrode potential -Define the electromotive force Nernst equation Prepare and make a laboratory experiments of electrolyte conductivity, EMF and Hittorf's number, - Calculate measurement data and interpret the results of the experiment, and write a lab reports	electromotive force (EMF) and Hittorf's number - Demonstrate skill calculating molar conductivity, degree of dissociation, activity coefficients, electrode potentials - Explain the relationship between EMS and the Gibbs energy and utility measurements EMS - Recognize the importance of cell production as the most efficient energy converters
10. Diffusion	-Define the concept of diffusion - Derive the first and second Fick's law - Define and describe the diffusion coefficient determination method	- Recognize and understand the significance of diffusion as a physical phenomenon that precedes chemical kinetics
11-15. The chemical kinetics	Define the rates of a chemical reaction, and the factors that affect the rate of chemical reactions - Define the reaction order - Describe the methods for determining the reaction rate constants and reaction order - List reactions to the kinetic mechanism of the elementary and complex - describe the kinetics of reverse,parallel, and consecutive reactions - describe the temperature dependence of reaction rate (Arrhenius equation) - Describe the theory of	Explain the importance of chemical kinetics, the rate of chemical reactions and impact to the rate of the reaction using catalysts, inhibitors and retardants - Experimentally determine rate constants, reaction order and interpret the influence of temperature on the rate constant - Demonstrate skill computing Understand and interpret the rate-determining step reactions

	transition state (activated complex) - Define the basic concepts of catalytic reaction Prepare and make a laboratory experiments: Decomposition of H_2O_2, Inversion of saharose - Calculate measurement data and interpret the results of the experiment, and write a lab reports	

FORM 2

1) Course teacher: Prof. Irena Škorić, Ph.D.
2) Name of the course: Organic chemistry II
3) Study programme (undergraduate, graduate):Applied Chemistry
4) Status of the course: undergraduate

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. to recognize and use the vocabulary of organic chemistry 2. to draw correct structural representations of organic molecules with functional groups 3. to use the knowledge from stereochemistry while analyzing mechanisms in organic chemistry mechanisms in organic chemistry 4. to write acceptable transformations and mechanism of reactions for aromatic, carbonyl and heterocyclic compounds 5. to compare the reactivity of each of the groups or organic compounds depending on their functional groups and reactions conditions 6. to suggest the most likely reaction pathway for new molecules that were not given as an example through the course 7. to derive the standard preparative procedures that are being used for synthesis of simple organic compounds	1. to use the knowledge in chemistry, chemical technology, especially the ones that are alinked with modern use in the biochemical systems 2. to be able to explain biochemical cycles using the knowledge on the overall strategy of metabolism 3. to estimate the influence of build and biological activity at the level of biomolecules 4. to apply the basic knowledge from applied chemistry in understanding the term of central dogma of molecular biology

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.Aldehydes and ketones; nucleophilic additions on the carbonyl group	- to use the vocabulary of organic chemistry for carbonyl compounds,	- to evaluate on the reaction path of the electrophilic addition of the given

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	heterocycles and nitrogen compounds; - to draw correct special representations of organic molecules that contain carbonyl and amino groups	heterocyclic compound
2. Carboxylic acids and their derivatives; Amines and like compounds with nitrogen	- to write acceptable transformations in the reactions of nucleophilic addition at the carbonyl group of an aldehyde, ketone, carboxylic acid or their derivative - to compare the reactivity of an amine depending on their structure	-to conclude on the possibility of mutual translations of the derivatives of carboxylic acids from one to another - to recommend synthesis for differently substituted aromatic compounds via diazonium salts from corresponding amines
3. Heterocyclic compounds; Synthetic polymers; Biomolecules	- to propose the most likely reaction pathway in the reaction of electrophilic addition at different heterocycles - to use the knowledge on the types of polymerization at given examples of synthesis of polymers	- to determine the alkalinity of heterocyclic compounds depending on their heteroatom - on the basis of the knowledge gained recommend different modifications of the structure of synthetic polymers in the interest of improvement of their properties

FORM 2

1) Course teacher: Hrvoje Ivanković	
2) Name of the course: Structure and properties of inorganic materials	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. An ability to apply fundamental science and engineering principles relevant to structure and properties of materials. 2. An ability to understand 3D form and nature of minerals and amorphous materials. 3. Be able to calculate parameters relevant for structure, physical properties and chemical stability of materials. 4. An ability to use the techniques, skills, and modern engineering tools necessary for precious description the structure and properties of materials.	**6) Learning outcomes at the level of the study programme:** 1. Be able to apply general math, science and engineering skills to understand the relationship between structure and properties of materials. 2. Be able to design and conduct experiments, and to analyze data. 3. Be able to organize and rationaly use time. 4. Be able to analyze and present (in written, spoken and graphical form) research results applying suitable computer.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Introduction to Crystallography	-To describe the connection among composition, structure, properties and processing of materials. -To describe crystal and amorphous state -To describe 3D periodic building of crystals -Using models be able to recognise crystal systems, 14 Bravais crystal lattices and	- To analyze and interpret connection between structure and properties of materials. -On the models, to show skills in observing 3D periodic building of crystals. - To understand and describe the relationship between external and internal shape of minerals.

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	symmetry elements - To calculate and interpret crystal planes, Millers indices, interplanar spacing, d.	
2. X-ray crystallography	-To describe the nature of X-ray and its forming -To describe X-ray diffraction from crystal lattice -To distinguish Laue and Bragg approach to x-ray diffraction on crystal lattice. - To describe and define reciprocal lattice and Ewalds sphere. -To prepare and perform the laboratory experiment of x-ray diffraction on unknown powder sample and analyse obtained results	-To explain behaviour of x-ray on crystal lattice -To explain and mathematically describe Braggs approach to x-ray diffraction on crystal lattice. - To apply experimentally x-ray diffraction on polycrystalline materials -To calculate crystallographic parameters from experimental data.
3. Introduction to crystal chemistry	-To describe and distinguish different crystal structures (compact packaging, coordination polyhedra, metallic, ionic and covalent structures). -To describe and draw some typical structures -To define and describe defects in crystal and thermodynamics of defects forming. - To define and distinguish properties of materials	- To analyze and interpret simple crystal structures -To explain and thermodynamically interpret defects forming in crystal structures. -To calculate equilibrium concentration of defects at assigned temperature. -To calculate and analyze from experimental data some mechanical and thermal

4.Materials properties and method of characterisations	(mechanical, thermal, optical and electromagnetically). -To describe and apply methods of characterisation (thermal and microscopic). - To prepare and perform laboratory testing and write the reports – To define thermodynamic parameters and to describe equilibrium in one- and two-component systems.	characteristics of material. -To know choose the right testing method. -To analyze and interpret one- and two-component phase diagram. -To calculate phase composition from phase diagram.

a) Course teacher: Assoc. Prof. Nenad Bolf, Ph. D.	
b) Course: Process Measurements and Control	
c) Title of the study program: Chemical engineering	
d) University education level: Undergraduate	
e) Academical year: 2	**f) Term : 4**
g) Teaching method:	**h) Hours (weekly)**
1. Lectures	2
2. Practical (laboratory) work	2
3. Seminar	0
4. Field teaching (days)	0
h) Aim of the course: To teach students on the process measurement, introduce them to metrology and its infrastructure, process dynamics and methods of automatic process control	
i) Course learning outcomes (4-8): 1. To determine process dynamic characteristics 2. To interpret features of transducers and transmitters 3. To get familiar with metrology infrastructure, standardization and accreditation system 3. To select transmitters for the flow, temperature, pressure, level, concentration and other process measurements 4. To read, interpret and sketch P & I diagrams 5. To design and tune the controller 6. To design simple regulatory schemes and automatic process control systems 7. To understand components and operation of modern process control systems	**j) Program learning outcomes:** 1. To apply chemical engineering methodology in the process development 2. To apply mathematic methods, models and techniques in solving examples 3. To perform process measurements and to control processes 4. To analyze and optimize chemical and related industry processes

k) Teaching units with associated learning outcomes and evaluation criteria		
Teaching unit	**Learning outcome**	**Evaluation criteria**
1. **Process control and control loop**	Understand the basics concepts of process control; Understand the purpose of the process control; Understand the structure and purpose of the control loop; Identity and select the components of the control loop; Set up a simple control loop mathematical model.	Describe and interpret the control loop operation. Develop control loop mathematical model.
2. Dynamic behaviour of the process	Identify the characteristics of the process dynamic response; Graphically and computationally determine the process time constant; Understand consequences of delays and dead times in the process and their influence on the process control.	To define input and output variables and parameters. To determine process parameters.
3. **Features of the transducers and their behaviour**	Understand the role and functioning of the measuring sensors and transducers; Interpret general features of transducers; Familiarize with dynamic behaviour of the signal transmission sensors and systems.	To calculate the parameters and estimate dynamic behaviour of transducers.
4. Transducers	Understand the function, and select the flow, temperature, pressure and level transducer; Understand the function, and select transducer of other process variables.	To select appropriate transducers for specific application.
5. Metrology and metrology infrastructure	Knowing the basics of legal metrology and metrology infrastructure; Knowing the role of measurement and testing laboratories, as well as standards and accreditation.	To explain the structure and importance of the metrology infrastructure.
6. Controller	Knowing the structure and understanding operation of proportional, integration and derivate controller;	To calculate the controller parameters based on dynamic process response.

	Tune up the controller and determine the controller parameters.	
7. Cascade control	Understand the purpose and operation of the cascade control; Choose variables and structure of the cascade regulation; Tune up cascade controller.	To draft the cascade control loops. To determine the controller parameters.
8. Feedforward control	Understand the concept of the feedforward control; Perform structural equation of the feedforward control for the given process;	To explain the concept of the feedforward control control.
9. Control valve	Know types and purpose of control valves, and understand their functioning; Determine the coefficient and characteristics of the valve; Know the factors influencing on dynamic behaviour of the valve.	To calculate valve coefficient and to estimate dynamic behaviour of the control valve.
10. Non-linearity compensation and adaptive control	Understand the nature and consequences of non-linearity; Adopt ways to compensate non-linearity; Understand the concept of adaptive control and tuning.	To explain the occurrence of non-linearity. To describe methods to compensate the non-linearity and adaptive control.
11. Structure of modern control systems	Identify the basics hardware components of the control loop; Know the elements of modern control systems.	To identify the elements of modern control loops.
12. Guidelines and new concepts of process control	Know the basic tools of statistical process control; Understand the basic applications of artificial intelligence and expert systems;	To list and explain basic methods of the statistical process control.

l) Student assessment

1. Assessment methods	**2. Examination**
- homeworks and seminars - colloquia/partial exams - written exams	- continuous monitoring and evaluating - written exams

m) Evaluation criterion

1. Continuous monitoring and evaluating

Activity and corresponding number of points		Evaluation criterion	
Activity	Points	Grade	Points
- colloquia	55	sufficient (2)	60-69
- laboratory	20	good (3)	70-79
- homeworks and seminars	20	very good (4)	80-89
- participation in class	5	excellent (5)	90-100
TOTAL	100		

2. Written exam

Activity and corresponding number of points		Evaluation criterion	
Activity	Points	Grade	Points
- Development of the dynamic process model	30	sufficient (2) good (3) very good (4) excellent (5)	60-69 70-79 80-89 90-100
- Calculation of the transmitter's characteristics	20		
- Making of a regulatory scheme	15		
- Calculation of controller's parameters	20		
- Sizing of an actuator and control valve	15		
TOTAL	100		

3. Oral exam – as required

FORM 2

1) Course teacher: Sanja Martinez, PhD, full professor
2) Name of the course: Electrochemistry
3) Study programme (undergraduate, graduate): undergraduate
4) Status of the course: obligatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
After learning students will be able to: - apply fundamental knowledge of electrochemistry to solve practical problems. - define the electrochemical phenomena and processes. - connect the electrochemical knowledge and methodology with knowledge of physical, analytical and general chemistry. - track and measure physical quantities in electrochemistry - use the electrochemical equipment	After learning students will be able to: - memorize the basic facts, concepts, principles and theories related to electrochemistry fundamentals, - identify and solve qualitative and quantitative electrochemical problems using suitable electrochemical principles and theory - apply knowledge in practice, especially in solving electrochemical problems on the basis of qualitative or quantitative information - monitoring, observe and measure electrochemical parameters, record and document them in a systematic manner

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Electrochemical equilibrium and electrochemical thermodynamics	After learning students will be able to: - present a clear picture of the basic electrochemical terms and concepts - give physical picture and describe mathematically types of conductivity and charge carriers - describe charge transfer in	After learning students will be able to: - define the basic electrochemical terms and use basic electrochemical terminology - define relevant electrical concepts and use relevant terminology in the field of electricity

	galvanic circuits with particular emphasis on the charge transfer through the metal / electrolyte and semiconductor / electrolyte interfaces - define electrochemical electrode potential, conduct the measurement of potential and describe various types of reference electrodes. - apply Nernst equation, - describe the double layer, its physico-mathematical background - give meaning of the electromotive force of a galvanic cell, thermodynamic parameters of a galvanic cell and thermal effects in a galvanic cell	- sketch galvanic circuits and distribution of potential in them - define the conditions of electrochemical equilibrium and conducted the associated calculations using the Nernst equation and table of standard redox potentials - describe and implement a potentiometric measurement - present graphically and mathematically models describing the double layer - demonstrate basic knowledge of thermodynamic functions and concepts applied to the electrochemical systems and carry out calculations of thermodynamic functions from laboratory measurements
2. Electrochemical kinetics and electrochemical processes	After learning students will be able to: - describe general mechanism of electrochemical reactions and all of its elementary stages - explain the kinetics of charge transfer and the concept of reversibility - explain electrochemical reaction under different conditions of transport of the reacting substance - use certain electrochemical techniques and methods - recognize engineering aspects of electrochemistry	After learning students will be able to: - reproduce electrochemical kinetics equation and all its borderline cases - use concepts of reversibility, irreversibility and quasi-reversibility - explain Fick's laws of diffusion and understand the relate them to the stationary/ nonstationary electrochemical reactions - demonstrate basic knowledge on the application of electrochemistry in different fields of science and technology

FORM 2

English language (basic course) third semester

COURSE AIM: The acquisition of competencies such as reading, oral and written fluency in English, illustrating usage of expert engineering terminology. Generating new vocabulary by using on line dictionaries on their own to recall pronunciation and meaning. Preparation of presentations for purposes of practicing oral interpretation for future international conferences. Students are also introduced to some customs regarding the cultures of the United States and the United Kingdom.
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:
General competencies: pronunciation of expert terminology that refers to various types of engineering and technology in English.
Specific competencies: writing a CV and illustrating usage of English grammar. Orally presenting a lab report which was previously filmed and placed in their e-portfolio.
STUDENT OBLIGATIONS: students are obliged to attend classes and solve all the revision tests in their e-class. They are also obliged to enter new vocabulary in the glossary of their e-class individually. They must have their indeks or ID card when writing midterm tests or final written tests.
SIGNATURE CONDITIONS: 80 percent attendance in each semester and taking part in class by engaging in class work. They must have a Euro pass CV and filmed lab experiment in their e-portfolio.
They must have a positive grade on their midterm test 1.
LECTURES METHOD: Lectures, language exercises in class such as reading, comprehension, pair work, group work, individual group work that is to be placed in their e-portfolios, revision of grammar by individually solving the revision tests in the e-class, consultations if need be every week.
MANNER OF ASSESSMENT AND TESTING:
Written midterm tests (60 percent or more on both midterm tests excludes the need for final written and oral exam)
Final written test (60 percent or more for passing grade) and oral exam (oral presentation of lab experiment in their e-portfolio)
QUALITY CONTRUL AND SUCCESS OF COURSE: Anonymous student survey
METHOD PREREQUISITES:
Access to a computer and knowledge of e-class password and e-portfolio password in Moodle and Merlin programs.
i) COURSE LEARNING OUTCOMES:
1 students will generate basic concepts of engineering terminology in English
2 students will demonstrate individual discovering of pronunciation of new vocabulary and the
definition of the newly acquired expert terms
3 students will demonstrate ability to use the e-portfolio for recording personal improvement
4 students will demonstrate recalling grammar by solving the revision tests in their e-class

j) PROGRAM LEARNING OUTCOMES:

1 students will recall expert terminology used in the various fields of engineering

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2 students will generate an advanced usage of grammar in the English language
3 students will recall how to write a CV, cover letter and reply to an job ad in the paper
4 students will use the Merlin and Moodle computer programs to do individual or group work
in their e-class and e-portfolio.

English language (advanced course) fourth semester

COURSE AIM: Acquiring competencies such as reading, oral and written fluency in English in the field of technology. Individual analysis of new vocabulary by using the on line dictionaries to discover the pronunciation and definition. Individual examination of revision tests in the e-class. Preparation for making oral presentations in English. Students also learn about the customs and cultures of the United States and the United Kingdom.
DEVELOPEMENT OF GENERAL AND SPECIFIC COMPETENCIES OF STUDENTS:
General competencies: pronunciation of expert terminology related to the field of technology in English. Understanding of expert terminology and usage both in written and oral form.

Specific competencies: oral presentation of lab report and entering new vocabulary in the glossary of the e-class. Recalling grammar by revision of tests in the e-class. Practising usage and pronunciation of new vocabulary.

STUDENT OBLIGATIONS AND MANNER OF FULFILMENT: Students are expected to attend at least 80 percent of all classes and are obliged to put their CV and group presentation in their e-portfolio. They are also expected to solve all revision tests in the e-class individually. They have to bring their indeks or ID cards during midterm and final tests.
SIGNATURE CONDITIONS: In order to get a signature at the end of each semester they must attend at least 80 percent of all classes and take part in language exercises, orally present their group work of the lab experiment conducted at the University and placed in their e-portfolio.
They must pass midterm tests 1 and 2.
LECTURE METHOD: Lectures and language exercises such as reading out loud, comprehension, pair work, group work and consultations when necessary.
ASSESSMENT METHOD AND EXAMINATION:
Written midterm tests (60 percent or more on both midterm tests excuses the student from having to take the final written and oral tests)
Final written test (at least 60 percent required to pass) and oral exam (presentation of lab experiment filmed as part of group work and put in their e-portfolio)
QUALITY CONTROL AND SUCCESS OF COURSE: Anonymous student survey
METHOD PREREQUISITES:
Access to a computer and demonstration of using the e-portfolio and e-class programs via passwords in the Merlin and Moodle programs intended for students of Zagreb University.

COURSE LEARNING OUTCOMES:
1 students will be able to use the basic terminology in the field of technology in English.
2 students will explain new vocabulary and arrange it in the e-class glossary individually
3 students will use the e-portfolio to record personal development

FORM 2

4 students will examine the revision tests in the e-class and recognise the grammar and be able
to use it in both written and oral communication

PROGRAM LEARNING OUTCOMES:
1 students will understand expert terminology used in the contemporary fields of technology
2 students will review and use English grammar at an advanced level
3 students will conclude how to present a lab report both orally and in writing
4 students will demonstrate usage of the e-class and e-portfolio in the Merlin and Moodle
programs intended for students of Zagreb University

FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD	
2) Name of the course: Polymers and Synthesis Processes of Polymer	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to understand the processes of synthesis of polymeric materials 2. to describe and understand the mechanisms of catalytic polymerization processes 3. to understand the knowledge related the basic elements of chemistry and material engineering 4. define the methods of product quality control 5. to work independently in the chemical and physical laboratory…..	**6) Learning outcomes at the level of the study programme:** 1. application of scientific principles underlying chemistry and chemical engineering on materials, their structure, properties, processing and performance 2. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form; 3. skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards; 4. awareness of the impact of material science and engineering solutions on society in the economic and environmental context,..

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Synthesis of polymers, mechanisms of chemical reactions:	- to indicate the type of polymerizations: emulsion, suspension… - to define mechanisms of polymerizations: chain, step, ionic polymerisation	-to interpret polymerization processes -to distinguish different type of polymerizations
2. Effect of conditions of chemical reactions on creation of various structure	- - acquisition of knowledge and understanding influence of catalysts type, temperature and time on formation of	-to recognize the type of condition and type of structure that is formed

of polymer	polymer chain structure and molecular weight - to explain the importance of creating a different structure of the polymer chains	-to define the various structure of polymers
3. Kinetic of various polymerization reaction ..	- to explain the importance of kinetic - to indicate the effect of kinetic on formation of different structure of polymer chain	- to define and explain kinetic -to distinguish kinetic and formed structure
4. Structure of polymer, properties and applications	- indicate basic type of polymers in relation to the application (thermoplastics, thermoset, elastomer) - to indicate the basic structure of polymers related to application (amorphous, crystal, fibres, adhesive, plastics..)	-to define type of polymer and the application -to explain relation of structure and application od polymer
5. Technological processes of polymers production	- to indicate the production process - acquisition of knowledge about the necessity of optimization the process - to acquired knowledge on the conditions of production on the properties and the end-use polymer - to indicate the methods for the assessment of control of production processes and product quality	-to define various technological processes - to explain effect of conditions of production on the properties - to define the methods of control of production processes and product quality
6. Introduction to plastic waste and basic principles of environmental protection	-to indicate the polymer waste stream - acquisition knowledge of basic principal of sustainable development, recycling of	-to define polymer waste - to explain sustainable development, impact and importance

FORM 2

	polymer	

FORM 2

1) Course teacher: Prof. Aleksandra Sander, PhD
Assis. Prof. Krunoslav Žižek, PhD

2) Name of the course: Unit Operations

3) Study programme: Undergraduate study programme Material Science and Engineering

4) Status of the course: Required

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Define properties of coarse disperse phase, methods of measurement, graphical interpretation and approximation of particle size distribution data. 2. To analyze mechanical separation processes. 3. To analyze mixing of homogenous and heterogeneous systems. 4. To analyze energetic and kinetic aspects of comminution process. 5. Explain and analyze the selected thermal separation processes. 6. Explain the utilization of energy separating agent and mass separating agent in the selected thermal separation processes. 7. . Define mechanisms of mass and heat transfer in the individual separation process and the corresponding individual and overall resistances. 8. To run experiments in lab scale units trying to estimate the parameters needed for process design.	1. Gaining of skills for a lab work. 2. Understand techniques and methods used in an industrial-scale plant and in quality of insurance. 3. Apply methodology for theoretical interpretation of experimental data. 4. Practise fundamental knowledges regarding core engineering courses.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Characterization of coarse disperse phase	- to analyze properties of coarse disperse systems - to recognize methods for characterization of coarse disperse phase, and to summarize interpretation and approximation of particle size distribution	- distinguish disperse system, disperse phase and disperse medium - define dispersity state and mixedness - explain the term of particle shape and concept of equivalent spheres

		(diameters) - sketch graph of particle size distribution data - practise theoretical knowledges regarding characterization
2. Mechanical separation processes	- to define efficiency of a separator - to describe sedimentation and filtration separation processes - to identify inlet and outlet variables	- distinguish total and grade efficiency of a separator - explain efficiency of a separator by using characteristic quantities - explain fundamentals of gravitational and centrifugal sedimentation - explain fundamentals of deep-bed filtration, cake filtration and centrifugal filtration
3. Mixing of fluids, suspensions and powders	- to define degree of mixing in homogenous and heterogeneous systems - to define primary variables that determine the mixing conditions - to analyze dynamic response of the process	- distinguish hydrodynamic conditions (flow regimes) for mixing of liquid-liquid and solid-liquid disperse systems - explain possible suspension states and suspending regimes - define powder types, mixture types and mixture quality - explain segregation phenomenon and its mechanisms - practise theoretical knowledges regarding mixing of suspensions
4. Comminution process	- to analyze energetic and kinetic aspects for comminution process	- explain models for estimation of energy consumption in comminution process - describe kinetics of a

FORM 2

		particle size reduction during comminution process
5. Heat exchangers	- define criteria's for classification of heat exchangers - analyze the performance of heat exchangers	- compare different types of heat exchangers - evaluate heat flow and heat transfer area - evaluate the efficiency of heat exchangers
6. Evaporation	- describe different types of evaporators - explain methods of evaporation - solve mass and heat balances and kinetic equation for heat transfer - explain energy saving methods	- schematically illustrate evaporator and define inlet and outlet process streams - know how to use tables and diagrams necessary for the calculations - calculate heat consumption and heat transfer area o fan evaporator - distinguish different types of evaporators
7. Separation with the addition or development of new phase	- explain separation by means of absorption, distillation and solvent extraction - explain phase equilibriums - define balance (mass and heat) and kinetic equations for selected separation processes - explain graphical and numerical methods for design of column separators - describe equipment and working principles of equipment	- schematically illustrate separation process with inlet and outlet process streams and the corresponding balance equations - based on the phase equilibrium and physicochemical properties of the components select solvent for extraction and absorption - illustrate process in the corresponding equilibrium diagrams - use graphical and numerical methods for dimensioning column separators (NTU, HTU, H, D) - distinguish columns with different types of internals

FORM 2

		(plates, packing)
8. Separation processes with the solid phase	- define methods of the selected separation processes - explain separation by means of crystallization and drying - define mass and heat balances - describe equipment and its working principles - explain energy saving methods for drying	- explain methods of crystallization (solution, melt, gas) - based on the solubility diagram select method of crystallization from solution - calculate mass of crystals and heat consumption of the crystallizer (mass and heat balances) - use humidity charts when solving numerical examples related to drying - illustrate and explain the drying curves - apply theoretical knowledge about batch crystallization from solution and drying in practical measurements

FORM 2

1) Course teacher: prof.dr.sc. Emi Govorčin Basjić	
2) Name of the course: **Structure and properties of polymer materials**	
3) Study programme (undergraduate): Material Science and Engineering	
4) Status of the course: Mandarory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Distinguish molecular structure and super molecular structure of polymers and identify morphology of polymer 2. Relate structure of polymers and viscoelastic properties with properties of polymers and application of polymer materials 3. Explain dynamic structure and properties of viscoelastic materials at static and dynamic strain 4. Estimate of polymer materials in different process of degradation 5. Define of structure and properties of multiphase polymer systems	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of structure and properties of polymer materials and changes of structure with heating and mechanical strain 2. Ability to apply gained knowledge in durability of materials in production processes and in application 3. Ability to analyse of polymer materials with different instrumental technique of analysis 4. Ability to design structure and properties of new multiphase polymer materials

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Static structure of polymers	Distinguish the molecular structure and super structure of polymers, distinguish the static and dynamic structure and morphology of polymers	
2. Dynamic structure of polymers	Distinguish the dynamic structure of polymers, relate the dynamic structure of polymers and properties of polymer materials	

3. Deformation states of thermoplastics,duromers and elastomers	Distinguish the dynamic structure and properties of thermoplasts,duromers and elastomers in heating process	Report of laboratory exercise on DSC and MDSC instruments
4. Viscoelasticity, deformation of liquids and solids	Distinguish the dynamic structure and properties of thermoplasts,duromers and elastomers at oscillating strain	Report of laboratory exercise on DMA instrument
5.Stability, physical process of degradation, degradation, ageing and flammability of polymer materials	Estimate of stability of polymer materials, explain the process of degradation and ageing and flammability of polymer materials	Report of laboratory exercise on the photooxidative and thermooxidative degradation of polymer materials
6. Multiphase polymer systems	Ability to define structure and properties of multiphase polymer systems	Analysis of morphological structure and properties of multiphase polymer systems with DSC, DMA, TGA i SEM technique Exercise and report.

University of Zagreb
Faculty of Chemical
Engineering and Technology

FKITMCMXIX

FORM 2

1) Course teacher: prof. dr. sc. Stanislav Kurajica	
2) Name of the course: Thermodynamics and kinetics of materials	
3) Study programme (undergraduate, graduate): Materials science and engineering (undergraduate)	
4) Status of the course: Mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To reproduce basic thermodynamic principles and to apply them for understanding, observing, anticipation and governing the processes occurring in the course of production and use of materials. 2. To perceive the influences of thermodynamic and kinetic parameters on production process paths, obtained microstructures and properties of materials. 3. To connect knowledge of mathematics, chemistry, chemical engineering and structure and properties of materials in order to identify, formulate and solve problems in the area of production and application of materials. 4. To analyze the behavior of materials on macro level having in mind structure and microstructure of material and phenomena on micro level 5. To develop critical way of thinking on materials production process path and influences on material in the course of usage. 6. To realize professional standards, to promote work ethics and to gain motivation for further education. 7. To improve the ability of analytical thinking and synthesis of knowledge, communication skills, criticism and ability to derive conclusions. 8. To use instrumental techniques of analysis of materials and to improve computer using skills as well as ability of analysis and	**6) Learning outcomes at the level of the study programme:** 1. Application of scientific principles underlying chemistry, physics and chemical engineering on materials, their structure, properties, processing and performance. 2. Understanding and integration of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues. 3. Knowledge of various kinds of materials and technologies for their production, including novel materials (nanomaterials, biomaterials). 4. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 5. Capability for further learning. 6. Ability to apply gained knowledge in materials production processes, quality control, and their improvement. 7. Skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards. 8. The ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering.

synthesis of data.	

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Thermodynamics of materials and phase equilibria	- Reproducing thermodynamic laws, principles and concepts and their application for understanding of structure and properties of materials. - Applying thermodynamic laws and parameters for interpretation and anticipation of changes in the system. - Perceiving thermodynamic parameters important for interactions of material and environment and to be able to anticipate the behavior of material after the change of the conditions - Knowing of basic concepts of the thermodynamic of materials and phase equilibria and the ability of interpretation of single component phase diagrams.	Ability to define: - reversible and irreversible process, - microstate, macrostate and multiplicity, - entropy through multiplicity, - surface energy, - system, component, phase, heterogeneous and homogeneous system, equilibria and the degree of freedom, - monotropic and enentiotropic Ability to differentiate: - state function and process function, - thermal and configurational entropy, - invariant, monovariant and divariant system, - phase transformations of first and second order. Ability to calculate: - equilibrium concentration of crystal lattice defects, - crystall lattice energy of ionic crystals, Ability to explain the influence of bond energy on properties of materials. Ability to specify Gibbs phase rule and meaning of variables. Ability to plot single-component phase diagram and to explain Le Chatelier’s rule.
2. Equilibrium phase	- The understanding,	Ability to describe:

diagrams of two-component condensed systems	interpretation and construction of phase diagrams. - The awareness of parameters influencing genesis of microstructure and the behavior of material. - The ability to explain the characteristics of two-component phase diagrams and to interpret process path in the course of cooling or heating the system. - The ability to differentiate eutectic, peritectic and monotectic reaction and to identify and interpret phase diagrams of systems with chemical compound that melts congruently and incongruently. - The ability to apply phase diagram in order to anticipate and direct materials production process path and to anticipate the influence process path on microstructure of material.	- the progress of cooling of melt with specific composition, - the progress of heating of solid with specific composition, - possible types of microstructure in two component system, - peritectic reaction, - monotectic system and cooling path in this system. Ability to determine the composition of eutectic system at certain temperature. Ability to plot: - microstructure of eutectic system after solidification for different melt compositions, - phase diagram of two-component system with chemical compound melting incongruently. Ability to define a characteristic composition intervals in peritectic system where compound is generated with or without remaining of primarily crystallized phase and to describe process path in both cases.
3. Phase diagrams of solid solutions	- The distinguishing between the concepts of ideal, regular and real solution, to distinguish between supstitutional and interstitial solid solution and between eutectoid and peritectoid reaction. - The ability to connect thermodynamic conditions for equilibria and thermodynamic properties of solutions with phase diagrams. - The interpretation of phase	Ability to state: - differences between substitutional and interstitial solid solution, - Hume-Rothery rules, to explain the reasons and consequences of fractional crystallization. Ability to describe: -cooling path in solid solutions with partial mixing, - methods of determination of phase diagrams, - cooling path in eutectoid and peritectoid systema,

	diagrams of solid solutions with complete or partial mixing and simple three-component phase diagrams. - The use different sources of data such as tables, diagrams and databases in the course of analysis or anticipation of process path and to use instrumental methods for the determination of simple phase diagrams.	- microstructure of complex two-component system in dependence on composition, cooling path and subsequent thermal treatment.. Ability to calculate Gibbs energy of phases in system and liquidus and solidus curves. Ability to determine phase diagram using cooling curves method. Ability to recapitulate invariant reactions.
4. Kinetics of materials	- The ability to list kinds and mechanisms of diffusion in crystal lattice, to describe mathematically diffusion process and to state factors influencing the diffusion coefficient. - The ability to distinguish between homogeneous and heteroheneous nucleation, to define crytical radii of nuclei and to explain the dependence of nucleation rate on temperature. - Knowledge of fundamental concepts of solid-state kinetics and kinetic models of reactions in the solid-state. - The perceiving of factors defining the rate of overall solid-state reaction and to determine the controlling kinetic factor, to state the models for the processes limited by diffusion, reaction on the interface and nucleation and growth ant to perceive advantages and disadvantages of certain models. - The ability to anticipate te effect of kinetic parameters	Ability to state: - mechanisms of diffusion in crystal lattice, - factors influencing diffusion coefficient, - basic assumption of kinetic investigations under non-isothermal conditions. Ability to define: - nucleation, driving force of nucleation process and resistances to nucleation process, - the change of Gibbs energy for nucleation and critical radii of nuclei, - the rate of reaction in heterogeneous systems, - the extended and true degree of conversion and their relationship. Ability to describe: - the dependence of nucleation rate on temperature and the reasons for such dependance, - the differences between homogeneous and heterogeneous nucleation, - geometrical models of solid-state reactions, - general alpha-t curve,

	on path and outcome of solid-state reactions. - The use of the methods of thermal analysis of materials in order to determine thermodynamic and kinetic parameters of materials and to conduct kinetic analysis of crystallization process in isothermal and non-isothermal conditions.	- isoconversional method, Ability to mathematically describe the diffusion process. Ability to list: - Solid state processes according to the reaction rate controlling process, - the basic characteristics of solid-state reactions, - the laws of nucleation. Ability to write kinetic equations for nucleation and growth processes and to describe the meaning of certain parameters. Ability to distinguish methods of non-isothermal kinetics analysis according to mathematical derivation and experimental conditions.

FORM 2

1) Course teachers: Danijela Ašperger, Hrvoje Ivanković; Zlata Hrnjak-Murgić; Emi Govorčin Bajsić; Mirela Leskovac	
2) Name of the course: Characterization of materials	
3) Study programme (undergraduate, graduate): undergraduate **Material Science and Engineering (3rd year, 6th semester, univ. bacc. ing. cheming.)**	
4) Status of the course: regular	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Based on theoretical insights be able to distinguish appropriate instrumental method of material characterisation as well performed measurements, interpreted and evaluated results. 2. Explain the connection between basic knowledge in the application of instrumental analysis. 3. The ability to work autonomously on the instruments in the laboratory for instrumental analysis and further autonomously study having a positive attitude about the need for the development of professional competencies. 4. Integrate acquired knowledge and apply them in problem solving and decision making in analytical practice.	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of important scientific principles of chemistry and engineering materials: structure, properties and application of materials. 2. Ability of independent or team work in the laboratory and the presentation of work in written and oral form 3. Chemical and physical laboratory skills, use of laboratory equipment and implementation of good laboratory safety practice. 4. Ability to apply and develop understanding of the techniques and methods applied in production, and quality control, as well as understanding of their limitations.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to instrumental methods, types of analytical signal and calibration procedures to determine the composition of materials.	- Recognize the techniques of instrumental analysis, identify and recognize the instrumental methods of classical and argue the need for calibration of methods. - Use theoretical knowledge	- Classify, define and explain basic theoretical knowledge of the analytical instrumental methods in materials characterization. - Select instrumental analytical method for analysis the analyte

	related to methods of instrumental analysis (spectrometry, electroanalytical, thermochemical, instrumental separation methods) and the working principles of instruments and procedural knowledge and skills related to practical performance measurement. - Ability to record experimental data and write reports autonomously.	in sample. - Choose adequate calibration method for given example (analyte, sample, instrumentation). - Describe the principle of instrumental method. - Concisely describe the experimental work - aim, methods, and results. - Autonomously interpretation the results in laboratory report.
2. Introduction to materials characterization using X-rays. Materials analysis by X-rays; X-ray fluorescence (XRF) and diffraction (XRD) analysis - nature of X- rays, formation and absorption of X-rays, theory of XRD, diffraction on single-crystal and powder.	- Understand the process of qualitative mineral characterization by XRD. - Evaluate, predict and comment on particular behavior of materials by examining XRD data of materials structures.	- Determination of mineral composition by recording of unknown sample of crystalline powder by XRD. - Determination of unit cell parameters of the mineral from XRD scan.
3. Introduction to the characterization of polymer materials and the spectroscopy methods	- Indicate the basics of polymer characterization. - Define determination of molecular weight (GPC method. - Ability to apply spectroscopic methods: UV, FTIR, NMR.	- to explain the determination of molecular masses of polymers - to explain basic principal work of spectroscopic methods, in general - to explain principal work of FTIR spectroscopy - to explain principal work of NMR and UV spectroscopy methods
4. Explain the behaviour of materials in heat Characterization and selection of materials for application Assess of material durability	- Ability to apply thermal techniques for characterization of materials and evaluating the quality of the product	- Report of laboratory exercise of polymer materials characterization by DSC, DMA and TGA techniques
5. Basic insight to mechanical properties,	- Understanding relationship between microstructure and	- Determine and explaine mechanical properties of

morphology and surface characteristics of materials	mechanical properties (metals, ceramics, polymers, composites) - Acquire knowledge about theoretical basis of various microscopic techniques and their application in material characterization. - Acquire insight to defining the surface and interface characteristics and to apply instrumental techniques for determining the surface free energy.	different materials obtained by tensile, stress relaxation and cyclic testing measurements. - Explaine and propose appropriate microscopic techniques as well analyse microscope images of different materials obtained by different microscopy techniques - Determine surface free energy of different materials by contact angle measurement and to apply appropriate model for SFE calculation as well explaine obtained results.

FORM 2

1) Course teacher: Prof.Nevenka Vrbos,Ph.D
2) Name of the course: INORGANIC NON-METAL MATERIALS
3) Study programme (undergraduate, graduate): pregraduate 6 th term
4) Status of the course: compulsory

5) Expected learning outcomes:	**6) Learning outcomes at the level of the study programme:**
1. Knowledge of technologies of production of inorganic nonmetallic materials; 2. Knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing and performance of materials; 3.Awareness of the impact of material science and engineering solutions on society at large; 4. Explanantion of methods for further learning on the subject matter, both in academic and in-industry terms.	1. Knowledge and understanding of scientific principles, underlying science and engineering, especially in chemistry, physics, mathematics and chemical engineering; 2. Knowledge of various kinds of material properties, especially ceramics, polymers, metals and alloys; 3. Ability to apply the acquired knowledge in materials' production processes and quality control; 4. Ability to identify ,formulate and solve material science and engineering problems.

7) Teaching units with corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.RAW MATERIALS	- understanding the process of formation of rock and minerals; - identifying the impact of conditions on the morphology of mineral origin.	- rocks, minerals, crystalline and amorphous definition sheets; - ability to indicate the class of minerals, physical properties of minerals and the rules of crystallography.
2.MINERAL BINDERS	- undrstanding hydration process; - knowledge of the most important cement composites and concrete additives for the	- ability to define and describe the processes of hydration - ability to explain the effect of cement waterproofing

	preparation of concrete and water-proofing materials.	material on concrete waterproofing.
3.GLASS AND CERAMICS	- adoption of general knowledge of glass and crystallization process; - structure and properties of glass ceramics	- ability to describe methods of ceramic formation; - ability to define the glass transition point.
4.RECYCLING AND SUSTAINABLE PRODUCTION	- knowledge of sustainable development concepts; - understanding of organic production of inorganic non-metallic materials.	- ability to specify the constituent elements of the paradigm of sustainable development.

FORM 2

1) Course teacher: Helena Otmačić Ćurković	
2) Name of the course: Metallic materials – corrosion and protection	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course:	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): **Student will be able to:** 1. apply basic knowledge of electrochemistry and chemical engineering to interpret corrosion processes 2. recognize different types of corrosion, their causes and consequences 3 identify key chemical and physical properties of metallic materials 4. discus new trends in development of structural materials 5. explain the principles of different corrosion protection techniques	**6) Learning outcomes at the level of the study programme:** 1.knowledge and understanding of scientific principles underlying material science and engineering, especially in chemistry and chemical engineering, 2. knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, 3. knowledge on metallic materials, 4. an introductionary knowledge to advanced materials and technologies, 5. awareness of the impact of material science and engineering solutions on society in the social, economic and environmental context 6. ability to identify, formulate and solve material science and engineering problems

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Fundamentals of corrosion processes	- explain the causes of corrosion -explain the mechanism of chemical and electrochemical corrosion processes - analyse possibility of	- draw corrosion cell - determine possibility of corrosion reaction by using Pourbaix diagram -discriminate anodic polarization curves of

FORM 2

	corrosion occurrence in dependence of given thermodynamic parameters -explain metal passivity	passivating and non passivating metals - perform corrosion potential measurement
2. Types of corrosion	-explain corrosion mechanism in given environment -explain difference between general and localized corrosion -explain the mechanism of initiation and propagation of different types of localized corrosion	-student should identify causes of corrosion in given medium -write corrosion reactions for given situation
3. Corrosion rate	-apply several experimental methods to determine corrosion rate -evaluate which experimental method or combination of methods are the most appropriate for examination of given corrosion system	-should explain the principles of various experimental methods for corrosion rate determination, in which conditions each one of them can be applied and what kind of information can be gained - in laboratory determine corrosion rate by electrochemical, gravimetric and volumetric methods
4. Corrosion protection methods	- students will be able to explain the basic design principles related to corrosion protection - explain the basics principles of electrochemical corrosion protection methods - explain the basics principles corrosion protection by corrosion inhibitors - explain the basics principles of corrosion protection by organic, inorganic and	- give an example of bad and good design solution from the corrosion protection point of view -draw scheme of cathodic protection system - define corrosion inhibitors and explain how they decrease corrosion rate - explain different procedures of coating application

	metallic coatings -explain how each corrosion protection method can be applied - conclude which corrosion protection method is suitable for given corrosion issue	
5. Physical properties of metallic materials	-explain the most important physical properties of metallic materials - explain how they can be determined	- explain given physical property and how it can be measured
6. Important metallic materials	- describe the most important chemical and physical properties of metallic materials, -describe the common application areas of the most important metallic structural materials	- describe the most important chemical and physical properties, as well as the common application areas of given metallic material
7. Advanced metallic materials	-explain the basic principles and structure of smart and biomimetic materials	-explain the basic principles of smart and biomimetic materials

FORM 2

1) Course teacher: Prof. Irena Škorić, Ph.D. Prof. Vesna Volovšek, Ph.D.	
2) Name of the course: Molecular spectroscopy	
3) Study programme (undergraduate, graduate): (undergraduate)	
4) Status of the course: optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to be able to explain the physical basis of certain molecular spectroscopy's; 2. to know how to choose appropriate spectroscopic method; 3. to be able to extract relevant data from spectra; 4. to know how to correlate obtained data; 5. to combine spectroscopic methods 6. to develop a logical approach to solving with recommendation of an acceptable structure for the given spectroscopic tasks;	**6) Learning outcomes at the level of the study programme:** 1. to apply spectroscopic methods in analysis of the given substrate; 2. to use spectroscopic methods in monitoring of an reaction process; 3. to apply the acquired knowledge in research projects; 4. the ability of selection of appropriate spectroscopic methods in monitoring of use of different materials and in a critical data analysis;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.Physical basis of molecular spectroscopy	- to determine the kind of interaction of electromagnetic radiation and mater for each of the spectroscopic methods - to explain the ways of detecting signals	- to determine the suitable spectroscopic method - to determine the number of suspected spectroscopic bands, their shape, half width and intensity
2. Different spectroscopic methods (IR, UV/VIS, MS, NMR)	-to define the wave region - to recognize the functional groups and chromophores in IR and UV/VIS spectra;	-to recognize and interpret spectra of simple molecules; -to determine the structure of the compound on the basis of

	- to determine the molecular ion and find characteristic fragments in the MS spectra; -to assign the signals in ^{1}H and ^{13}C spectra to appropriate structural units; - to be able to suggest the structure of the compound on the basis of spectral data;	the given spectra

a) Course teacher: Assoc. Prof. Nenad Bolf, Ph. D.	
b) Course: Process Measurements and Control	
c) Title of the study program: Chemical engineering	
d) University education level: Undergraduate	
e) Academical year: 3	**f) Term : 6**
g) Teaching method:	**h) Hours (weekly)**
1. Lectures	2
2. Practical (laboratory) work	1
3. Seminar	-
4. Field teaching (days)	-
h) Aim of the course: Instruct students to use the software package MATLAB/Simulink and its advanced functions for chemical engineering calculation, display and analysis of measurement data, modelling and process optimization.	
i) Course learning outcomes (4-8): 1. Solve systems of equations by matrix calculation in a software package 2. Apply advanced features for analyzing and displaying data 3. Perform symbolic functions and calculations 4. Analyze measurement data using the Statistics, Curve Fitting, Spline and System Identification Toolbox 5. Develop process models in a graphical user interface using the Simulink 6. Solve examples of continuous, discrete and hybrid systems	**j) Program learning outcomes:** 1. To apply chemical engineering methodology in the process development 2. To apply mathematic methods, models and techniques in solving examples 3. To perform process measurements and to control processes 4. To analyze and optimize chemical and related industry processes

k) Teaching units with associated learning outcomes and evaluation criteria		
Teaching unit	**Learning outcome**	**Evaluation criteria**

MATLAB / Simulink. Environment, interface and basic operations. Manipulating vector, matrices and fields. Data structures and programming.	Solve systems of equations by matrix calculation using the software package.	Solve the system of equations by matrix calculation.
Process and system simulation. Methods and tools for simulation. Plotting and graphic display.	Apply advanced features for solving, displaying and data analyzing.	Solve and analyze the dynamic model of process/ system applying numerical methods.
Symbolic computation fundamentals. Using functions for symbolic computation.	Solve symbolic expressions and equations and linear algebra examples. Apply special functions in the graphical environment.	Solve given symbolic expression or equation.
Data processing in Curve Fitting Toolbox. Parametric and nonparametric fitting. Spline Toolbox.	Process measurement data and calculate fitting statistical. Apply the method of linear and non-linear regression using parametric and non-parametric models. Linear and nonlinear fitting procedures.	Implement regression analysis and data processing in the program interface.
System identification. Parametric and non-parametric identification. Model validation.	Develop a dynamic model of process/system using identification methods. Derive the model in a graphical environment.	Solve the example of dynamic identification based on the real plant data.
Simulink fundamentals. Developing process/system model. MATLAB/Simulink connectivity and interaction.	Develop continuous, discrete, and hybrid models of linear and nonlinear systems.	Develop a process/system model in a graphical environment by using block diagrams.
Programming in the Simulink graphical environment.	Simulate and analyze dynamic systems in the graphical environment.	Conduct a simulation and analyze the simulation results.

l) Student assessment

1. Assessment methods	**2. Examination**
- homework and seminars - colloquia/partial exams - computer simulation	- continuous monitoring and evaluating - computer exams

m) Evaluation criterion

<table>
<tr><td colspan="4">1. Continuous monitoring and evaluating</td></tr>
<tr><td colspan="2">Activity and corresponding number of points</td><td colspan="2">Evaluation criterion</td></tr>
<tr><td>Activity</td><td>Points</td><td>Grade</td><td>Points</td></tr>
<tr><td>- computer simulation
- colloquia/partial exams
- participation
TOTAL</td><td>55
40
5
100</td><td>sufficient (2)
good (3)
very good (4)
excellent (5)</td><td>60-69
70-79
80-89
90-100</td></tr>
<tr><td colspan="4">2. Written exam</td></tr>
<tr><td colspan="2">Activity and corresponding number of points</td><td colspan="2">Evaluation criterion</td></tr>
<tr><td>Activity</td><td>Points</td><td>Grade</td><td>Points</td></tr>
<tr><td>- Solving of a system of equation</td><td>20</td><td rowspan="6">sufficient (2)
good (3)
very good (4)
excellent (5)</td><td rowspan="6">60-69
70-79
80-89
90-100</td></tr>
<tr><td>- Solving of a symbolic equation</td><td>10</td></tr>
<tr><td>- Statistical data analysis</td><td>20</td></tr>
<tr><td>- Identifying process models</td><td>25</td></tr>
<tr><td>- Model development in the Simulink</td><td>25</td></tr>
<tr><td>TOTAL</td><td>100</td></tr>
<tr><td colspan="4">3. Oral exam – as required</td></tr>
</table>

FORM 2

1) Course teacher: Prof. dr. sc. Stanislav Kurajica and prof. dr. sc. Sanja Lučić Blagojević
2) Name of the course: Introduction to nanotechnology
3) Study programme (undergraduate, graduate): Applied Chemistry (undergraduate)
4) Status of the course: Electional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. The ability to explain certain properties of materials and to understand the reasons for change of properties occurring on nano-scale. 2. The understanding of ideas, concepts and techniques in the field of nanotechnology and the ability of their critical judgment. 3. Distinguishing of top-down and bottom-up methods of nanofabrication, the understanding of these methods and being able to perceive their advantages and disadvantages. 4. The ability to analyze the purpose and to apply knowledge of materials science and engineering in nanotechnology 5. To explain connection between structure and properties of nano-objects and integrated nano-systems. 6. To describe different methods of characterization on nano-scale and to know principles of these methods and perceive their advantages and idsadvantages. 7. To perceive momentary limitations in the development of nanomaterials and ethical doubts appearing in the field of nanotechnology. 8. To demonstrate communication skills, ability of critical thinking and cognition of the need for further learning.	1. Competence in the evaluation, interpretation and synthesis of chemical information and data. 2. Competence in presenting chemical and chemical engineering related material and arguments in writing and orally, to an informed audience. 3. Capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information. 4. Carry out standard laboratory procedures and use instrumentation involved in synthetic and analytical work, in relation to both organic and inorganic systems. 5. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof. 6. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 7. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 8. Study skills and competences needed for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation

FORM 2

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The properties and characterization of nanomaterials	- Knowing of terms in the field of nanoscience and nanotechnology. - The understanding of the properties of materials (especially physical, mechanical, chemical, optical, electrical and magnetic) and causes for the change of properties on nano-scale. - Knowing of the principles of typical methods for the characterization of nanomaterials (especially transmission and scanning electron microscope as well as scanning tunneling microscope and atomic force microscope. - The combination of knowledge on structure and properties on nano-scale with the aim of perceiving of application potential of nanomaterials and nanoproducts.	- The listing of typical characteristics of nanotechnology. - Explaining terms typical for nanomaterials and nanotechnologies - Explaining terms connected to various properties of materials and connection between structure and properties of materials. - Explaining reasons for changing of certain properties on nano-scale - Describing operating principles of typical methods of nanomaterials characterization. - The listing of constrains, advantages and disanvantages of certain methods. - Describing preparation of samples for certain methods of characterization.
2. Nanofabrication, manufacturing, trends and applications of nanomaterials	- The differentiation between top-down and bottom-up methods of nanofabrication. - Understanding of principles of these methods, controlling factors and limitations (especially lithography, dip-pen nanolithography, crystallization, sol-gel method, chemical vapor deposition, self-assembly and nanomanipulation. - Understanding of ideas, concepts, techniques and trends in the field of	- List the methods of manufacturing - List and explain classification of nanomanufacturing methods - List most important nanomanufacturing methods from each category. - Describe the most important methods, advantages, disadvantages, limitations, controlling factors. - List some nanoproducts already at the market. - List main areas of investigation in

FORM 2

	nanotechnology (especially in electronics, medicine, materials engineering and environmental protection) and the ability of their critical judgment. - Perceiving of ethical doubts appearing in the field of nanotechnology and the ability to discuss on them.	nanotechnology, aims of these investigation, assumtions they are based on and the purpose of aimed nanoproducts. - List some of the potential risks associated with nanotechnology.
3. Nanoobjekti	- Recognition of the role of materials science and engineering in synthesis of nanoobjects. - Connection between structure and properties of nanoobjects. - Understanding of principles of chemical and physical modifications of nanoobjects surfaces.	- Describe synthesis processes of certain nanoobjects. - Explain connection between structure and properties of nanoobjects and specificities in relation to bulk materials. - Explain and analyse the manners of sertain nanoobjects modification.
4. Selected nanotechnologies (nanobiotechnology, nanoelectronics, polymer nanocomposites)	- The recognition of scientific and technological acheivements realised in the area of nanotechnology. - The insight in realized and potential acheivements in certain areas of nanotechnology. - The analysis of the purpose of nanoobjects for certain applications in integrated systems.	- Explain the purpose and define contribution of certain areas of nanotechnology and give examples from literature. - Describe examples in certain areas of nanotechnology. - Explain the purpose of nanoobjects and other components of integrated systems.

University of Zagreb
Faculty of Chemical
Engineering and Technology

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FORM 2

1) Course teacher: Assoc. Prof. Elvira Vidović, PhD
2) Name of the course: Polymer Biomaterials
3) Study programme (undergraduate, graduate): undergraduate
4) Status of the course: elected

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
- to contrast characteristics of polymer materials to other materials regarding physico-mechanical, chemical and biological properties - to describe reaction mechanisms, synthesis and preparation procedure of polymer biomaterials - to analyze polymer biomaterials regarding their application - to define the processes of bioresorption and biodegradation of material - to describe the application of biomaterials in medicine - to explain implementation of *in-vivo* and *in-vitro* tests	1. to create solutions and independently solve problems (including their identification and formulation of the problem) in materials science and engineering. 2. to solve problems in production and performance of materials with the aid of chemical and physical techniques and instrumental methods of materials analysis.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Properties of biomaterials	- to describe characteristic properties of biomaterials: physico-mechanical, chemical, biological, surface	- to name characteristic properties of biomaterials: physico-mechanical, chemical and biological, surface
2. Degradation of biomaterial	- to identify materials regarding their bioresorption and biodegradation	- to classify materials regarding their bioresorption and biodegradation

FORM 2

1) Course teacher:

Prof. Sanja Lučić Blagojević, Ph.D.

Prof. Mirela Leskovac, Ph.D.

2) Name of the course:

Surface engineering

3) Study programme (undergraduate, graduate):

Graduate programme: Materials chemistry and engineering

4) Status of the course: regular

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. To explain and relate phenomena of surface and interface engineering (energy and thermodynamics of surface, adhesion, principles and application of tribology) in materials engineering.

2. To analyze and conclude about the chemical, structural, surface and interface characteristics in relation to the production and application properties of materials (composites, blends, adhesive materials).

3. To choose methods of surface modification and changes at the interfaces in multicomponent systems.

4. To use a variety of methods of analysis for the assessment of surface characteristics and quality of materials as a whole.

5. To execute and connect elements of adhesion parameters optimization, friction and wear reduction and improvement of the material properties in the given application conditions.

6) Learning outcomes at the level of the study programme:

1. To identify and connect scientific principles important for chemistry and materials engineering with the aim of their research and development.

2. To connect and deepen the basic elements of chemistry and engineering materials: structure, properties, production and use of materials.

3. To define the processes of production and modification of materials.

4. To demonstrate skills of work in the chemical, physical and process laboratory, using the techniques and methods in the production process and quality control.

5. To identify and resolve complex problems in the field of chemistry and engineering of materials, independently and / or as part of a multidisciplinary team, and to present a work in written and oral form.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

FORM 2

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Surface and interface phenomena	- to define the surface phenomena - to apply the adhesion theories in the optimization of adhesion according to the type of materials in contact - to apply instrumental techniques for determining the surface energy - to evaluate the theoretical and practical adhesion	- determine the surface and interface energy, wetting and adhesion work - explain and give an example of some theory of adhesion - demonstrate methods for measuring the surfaces energy and application of models - connect the parameters of adhesion with adhesive joint strength
2. Polymer surface and interface	- to define the specifics of polymer surfaces - to explain modification modes for polymer surfaces and influences on the structure and surface properties - to predict the structure and properties of the polymer-polymer interface according to the models	- analyze surface energy of various polymer materials in relation to the structure and composition - identify changes at the surface after treatment using specific techniques of surface characterization - explain and connect specific of polymer (molecular weight, solubility parameter) with fracture energy according to models
3. Interface in polymer composites and blends	- to assess miscibility and predict the morphology of multiphase systems (polymer blends, composites) - to apply the thermodynamic parameters of adhesion in the optimization of multiphase systems	- give examples and explain phase diagrams and morphology of miscible, partially miscible and immiscible polymer systems - calculate the parameters of adhesion and explain models that connect adhesion at the interface and properties of multiphase systems
4. Adhesive joints	- to analyze ways of joining materials	- conclude about the advantages and disadvantages of technologies for joining

	- to evaluate the quality of an adhesive joint	materials - analyze failure models and impacts on the strength of an adhesive joint
5. Tribology	- to predict the modes and mechanisms of friction and wear of various materials (metals, ceramics, polymers, composites and composite) - to connect wear at the micro and nano scale with the structure and properties of polymeric materials	- evaluate the friction and wear of different types of materials - compare the viscoelasticity and brittleness of polymer materials and tribological behavior during friction and wear

FORM 2

1) Course teacher: Full Prof. Katica Sertić-Bionda, PhD., Assoc. Prof. Elvira Vidović, PhD	
2) Name of the course: Petroleum Refining and Petrochemical Products	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: compulsory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to relate the characteristics of feedstocks (petroleum, natural gas) with characteristics of products (fuels, lubricants, monomers, polymers). 2. to identify the parameters in petroleum refining and petrochemical processes. 3. to recognize the effects of petroleum refining and petrochemical process parametrs on yields and composition of products. 4. to distinguish the relevance of processes regarding the application and ecological requirements on the products. 5. to outline the simple scheme of petroleum refining and petrochemical products production.	**6) Learning outcomes at the level of the study programme:** 1. to create solutions and independently solve problems (including thir identification and formulation of the problem) in materials science and engineering. 2. to solve problems in production and performance of materials with the aid of chemical and phisical techniques and instrumental methods of materials analysis.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Petroleum refining products: liquefied petroleum gas, motor gasoline, aviation fuels, diesel fuels, fuel oils, coke, bitumens, lubricating oils.	- to distinguish the relevance of processes regarding the application and ecological requirements on the products.	- to explain the relevance of processes regarding the application and ecological requirements on given petroleum refining or petrochemical product.

FORM 2

2. Pyrolysis – the primary process in petrochemical industry.	- to describe the reaction conditions of pyrolysis of hydrocarbons	- to explain the importance of hydrocarbons pyrolysis process and its products
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FORM 2

1) Course teacher: Marica Ivanković
2) Name of the course: Physical chemistry of polymers
3) Study programme (undergraduate, graduate): graduate, Materials Science and Engineering
4) Status of the course: mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. To describe the relationship between structure and properties of polymers 2. To apply fundamentals of General physical chemistry to define thermodynamic functions of polymer solutions and blends (enthalpy, entropy, Gibbs free energy of mixing) and to describe phase equilibrium in polymer solutions and blends 3.To prepare and perform laboratory experiments 4.To analyze and interpret experimental results 5.To write laboratory reports	1. To apply fundamentals of natural sciences to describe the relationship between structure and properties of materials 2. To perform simple experiments with available laboratory equipments and devices 3. To apply good laboratory safety practice 4. To present research results related to their study subject (orally and in writing)

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Structure of polymers	-To describe specific features of polymer structures -To distinguish ideal and real polymer chains -To interpret different models of ideal polymer chains (The freely jointed chain; the freely rotating chain, the	- To identify repeating units in particular polymer and to specify possible isomeric forms - To calculate the polymer coil dimensions (end to end distance, radius of gyration) based on assumed models

	hindered rotation model) -To distinguish and define averages of molecular weights and distribution functions of molecular weights	- To calculate different averages of molecular weights
2. Polymer solutions	-To define solubility parameter and to describe solubility parameter concept -To distinguish solvent quality (good, bad and theta solvent) -To define the specific, the reduced and the intrinsic viscosity of dilute polymer solutions -To describe the osmotic pressure of dilute polymer solutions -To prepare and perform laboratory experiments: 1. *Identification of polymers from solubility* tests 2. Swelling kinetics of polymers 3. Viscosimetry, intrinsic viscosity, viscosity- average molecular weights 4. *Viscometric determination of solubility parameters*, three-dimensional solubility parameters. 5. Osmometry, number-average molecular weight, second virial coefficient 6. Gel permeation	-To explain basic terms related to polymer solutions -To identify polymers from solubility tests - To determine experimentally solubility parameter, intrinsic viscosity, molecular weight distribution of particular polymer - To explain the relationship between intrinsic viscosity, polymer coil dimensions and solvent quality - To relate 2nd virial coefficient to the thermodynamic quality of solvent

FORM 2

	chromatography -To analyze and interpret experimental results -.To write laboratory reports	
3.Thermodynamics of polymer solutions and blends, phase equilibrium and phase diagrams	-To define the conditions for thermodynamic stability of polymer solutions and blends -To illustrate phase equilibrium and phase separation in phase diagrams -To derive the Flory-Huggins equation	- To analyze and interpret phase diagrams for simple binary systems - To explain the mathematical derivation of the Flory-Huggins equation -To apply Flory-Huggins equation

FORM 2

<table>
<tr><td colspan="2">1) Course teacher: prof. dr. sc. Stanislav Kurajica</td></tr>
<tr><td colspan="2">2) Name of the course: Silicate chemistry</td></tr>
<tr><td colspan="2">3) Study programme (undergraduate, graduate): Materials science and engineering (graduate)</td></tr>
<tr><td colspan="2">4) Status of the course: Mandatory</td></tr>
<tr><td>5) Expected learning outcomes at the level of the course (4-10 learning outcomes):
1. Knowing of basic terms connected to natural and synthetic silicate materials.
2. The ability to apply the principles of materials science and engineering for understanding the properties of silicates and processes occurring in the course of production and use of silicates.
3. Capability of connecting knowledge of chemistry, chemical engineering and structure and properties of materials in order to identify, formulate and solve problems in the area of silicate chemistry.
4. The ability of analyzing the behavior of silicates on macro-level having in mind structure and microstructure of material and phenomenon on micro-level.
5. The development of critical way of thinking on structure, properties, manufacturing and applications of silicates.
6. Recognition of professional standards and improvement of work ethics as well as gain motivation for further education and intellectual development.
7. Improvement of capabilities of analythical thinking and synthesis of knowledge, communication skills, criticism and ability to draw conclusions.
8. The capability to use instrumental techniques of materials analysis and to enhance computer skills, analysis and synthesis of data.</td><td>6) Learning outcomes at the level of the study programme:
1. Application of scientific principles underlying chemistry, physics and chemical engineering on materials, their structure, properties, processing and performance.
2. Understanding and integration of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues.
3. Knowledge of various kinds of materials and technologies for their production, including novel materials (nanomaterials, biomaterials).
4. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs.
5. Capability for further learning.
6. Ability to apply gained knowledge in materials production processes and quality control, and in their improvement.
7. Skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards.
8. The ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering.</td></tr>
<tr><td colspan="2">7) Teaching units with the corresponding learning outcomes and evaluation</td></tr>
</table>

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Silicij, $[SiO_4]$-tetraedar, silikati, klasifikacija silikata	- Knowing of basic terms of silicate chemistry. - Understanding of silicate minerals genesis. - Perceiving of the importance of silicates and the reasons of existance of numerous and versatile silicates. - Notation of similarities and differences of silicon and carbon chemical behavior. - Knowing of properties of silicon. - Interpretation of processes of obtaining technical and semiconductor silicon, CVD process, Czochralski process and floating zone process. - Distinguishing of various types of solar cells. - Interpretation of polycrystalline cells manufacturing process. - Explaining the nature of a chemical bond between silicon and oxigen as well as ways of connecting of $[SiO_4]$-tetrahedrons. - Applying of Pauling rules for building of ionic crystals on silicates. - Classifying of silicates and recognizing in which group certain silicate could be categorized. - Reproduction of concepts of dimension number, multiplicity, periodicity, branchedness and to determine these parameters for simple silicates.	To define: - silikates, - segregation coefficient. To distinguish - dimensional number, multiplicity, periodicity. To explain: - similarities and differences of chemistry of silicon and carbon, - differences of silicon reactivity in bulk form and in melt, - the nature of Si-O bond, - the ways of connecting of $[SiO_4]$ tetrahedral. To state: - four basic reasons of silicates diversity, - forms of Si on the market and approximate purity, - types of solar cells, - coordination polihedra pf usual ions in silicates, - three common ways of classification of silicates and what are they based on, - kinds of silicates according to structural classification. To describe: - process of manufacturing of technical silicon, - process of manufacturing of ultra-pure polycrystalline silicon, - method of conversion of polycrystalline silicon to monocrystal.
2. Island, group, ring and	- Knowing of most important	Define olivine.

chain silicates	groups of island silicates. - Understanding of the olivine structure - Understanding of the connection between structure and properties of island silicates. - The ability to explain the differences in structure, especially the coordination of aluminum in silimanite group minerals. - perceiving of role and importance of mullite in chemical industry. - Understanding of beryl structure. - The ability to explain chain silicates structures trough T-O-T units conformance. - perceiving similarities and differences between structures of pyroxenes and amphyboles. - Perceiving the reasons why some minerals are used as a gemstones or semiprecious stones. - Knowing of basic terms of gemstones processing and assesment.	State: -coordination numbers of aluminum in silimanite andalusite and kyanite, - how is defined periodicity of chain silicates. Describe: -the importance and role of mullite in porcelain microstructure and properties that it is meritorious in porcelain, - beryl structure, - basic structure of piroxenes and amphyboles. Explain - how are $[SiO_4]$-tetrahedra connected in olivine and how Mg^{2+} ions are coordinated with O^{2-} ions and vice versa, - how is 2^{nd} Pauling rule on the strength of valence in ionic structure is applied to olivine, - the influence of kation in polihedra on mechanical properties of silicates, - the influence of chain silicates structure to their properties. Distinguish ortopyroxenes and clinopyroxenes.
3. Layered silicates	- Knowing of important groups of layered silicates. - Understanding of the structure of layered silicates. - Ability to describe tetraherral and octahedral layer. - Ability to differentiate T-O and T-O-T layers. - Ability to explain terms of dioktahedral and trioktahedral structure. - Ability to differentiate various layer connection manners.	To state: -which types of structures have kaolinite and serpentine, - what are typical properties of vermiculite and montmorillonite, which are characteristics of their structures and what are the differences between them. - few uses of kaoline. - what factors influence sedimentation and coagulation stability of clay suspensions. Describe:

	- Interpretation of classification of layered silicates. - The ability to describe structures of kaolinite, serpentine, pyrophylite, talc, mica, chlorite, vermiculite, montmorillonite and illite. - The ability to explain the genesis of layered silicates. - Interpretation of clays classification. - Knowing of methods of bentonite modifications. - Understanding of colloid properties of clay and the ability to control the stability of suspension, plasticity, viscosity and flow properties. - Understanding of terms of exchange equilibria, selectivity coefficient, cation exchange capacity and ability to use them for the control og ion exchange process.	- the connection between layers in kaolinite, talc and muscovite, - the reasons of ion exchange property in clays, Explain: - the difference between trioctahedral and ioctahedral structure of layered silicates, - in what way will be changed the diffraction pattern of montmorillonite after addition of ethylene-glycole, or after heating to 400°C? - will it be any changes after the same treatment of kaolinite and why. - what is zeta-potential, on what it depends and how it can be influenced, explain with details both ways of influence. To differentiate clays of primary and secondary deposits.
4. Framework silicates and synthetic silica	- Knowing of important groups of framework silicates. - Ability to explain various factors on ordering of feldspars structures. - Understanding of zeolite structures. - Interpretation of zeolite classification. - Understanding of the mechanisms underlying zeolite application for drying, separation and catalysis. - Interpretation of zeolite manufacturing process. - Knowing of SiO_2 polymorphs and the variety of quartz. - Interpretation of Fenner's diagram.	To define: - factors influencing compatibility in the course of formation of the solid solution between two feldspars. - hydrogel, xerogel, aerogel To state: - most important feldspars and factors influencing ordering of their structure, - professional diseases connected with the work with crystalline silica, - classification of synthetic silica. Describe: Aerosil process Processes of obtaining silica-sol, silica-gel and precipitated silica.

	- Knowing of quartz raw materials. - Consciousness of SiO_2 influence to health. - Differentiation of various kinds of fine synthetic silica. - Interpretation of manufacturing procesess of pirogeneous silica, silica-sol, silica-gel, precipitated silica and post-processed silica.	Explain: - the role of feldspars in porcelain firing process, - why zeolites are called molecular sieves and why are they good ion exschangers. Describe structure of zeolites through hierarchy of structural elements. List modifications of silica depicted in Fenner's diagram. Differentiate stabile and metastabile modifications of silica, reconstructive and displacive phase transformations of silica.
5. Other inorganic silicate compounds and organosilicon compounds	To list, describe and differentiate other inorganic compounds of silicon. Interpretation of the manufacturing process of soluble alkali metal silicates. Describing and differentiation of silanes, halogen silanes, siloxanes, silanoles and alkoxysilanes and knowing their properties. Interpretation of silane manufacturing process. Knowing of organosilicon compounds, especially organohalogen silanes i organoalkoksi silanes and their chemical properties. Interpretation of manufacturing processes of organosilicon compounds. Knowing silicone properties. Interpretation of manufacturing processes of silicones. Differentiation of industrial silicone products, especially silicon oils, silicone rubbers, silicone resins. Perceiving need and methods for environmental protection	To define: - water glass To state: - classification of industrial silicon products, - most important properties of silicon-carbide, silanes, siloxanes, silanoles, and alkoxysilanes. To describe: - methods of obtaining of networked silicone polymers. - ways of environment endangerment with the processes of exploitation and manufacturing of silicates and to perceive methods of environmental protection - important solid-state reactions of silicates. To list and to describe various methods of silicate characterization.

	in processes of exploitation and manufacturing of silicates. Interpretation of thermal processes in silicate chemistry and important solid-state processes of silicates. To apply methods of structural characterisation, thermal analysis, electron microscopy and microanalysis for characterization of silicates.	

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FORM 2

<table>
<tr><td colspan="3">1) Course teacher: Hrvoje Ivanković</td></tr>
<tr><td colspan="3">2) Name of the course: Ceramic engineering</td></tr>
<tr><td colspan="3">3) Study programme (undergraduate, graduate): graduate</td></tr>
<tr><td colspan="3">4) Status of the course: mandatory</td></tr>
<tr><td colspan="2">5) Expected learning outcomes at the level of the course (4-10 learning outcomes):
1. An ability to apply fundamental science and engineering principles relevant to ceramic and glass production.
2. An ability to understand relationship among process parameters and properties of ceramic and glass products.
3. Be able to calculate process parameters relevant for structure, physical properties and chemical stability of ceramic and glass products.
4. An ability to use the techniques, skills, and modern engineering tools necessary for precious conducting of production processes.</td><td>6) Learning outcomes at the level of the study programme:
1. Be able to apply general math, science and engineering skills to understand the relationship between structure and properties of materials.
2. Be able to design and conduct experiments, and to analyze data.
3. Be able to organize and rationally use time.
4. Be able to analyze and present (in written, spoken and graphical form) research results applying suitable computer.</td></tr>
<tr><td colspan="3">7) Teaching units with the corresponding learning outcomes and evaluation criteria</td></tr>
<tr><td>Teaching unit</td><td>Learning outcomes</td><td>Evaluation criteria</td></tr>
<tr><td>1.Structure, properties and engineering of ceramics</td><td>-To recognize and describe common crystal structures
- To recognize and describe traditional and advance ceramics
-To describe sintering mechanisms and grain growth.
-To describe forming processes of ceramic</td><td>- To analyze and interpret connection between process parameters and structure and properties of ceramic materials.
-To analyze and interpret phase diagram
- To determine experimentally the mechanical properties of</td></tr>
</table>

FORM 2

	products - To organize and conduct laboratory experiments: 1. To prepare ceramic suspension for slip casting. 2. To determine the rheological properties of ceramic suspensions. 3. To determine draying and sintering curves and to conduct draying and sintering process.	ceramic bodies. -To determine experimentally the apparent density and porosity of sintered ceramic body.
2. Structure, properties and engineering of glasses	-To describe and distinguish between glass and structure of crystal materials. -To describe basic elements of classical theory of glass structure -To describe theory of glass crystallization, nucleation and crystal growth. - To describe glass forming processes. -To prepare and perform the laboratory experiment: 1. Calculating and preparing glass mixture. 2. Glass melting 3. Glass characterization -To analyze and interpret experimental results and to write laboratory report	- To analyze and interpret connection between process parameters and structure and properties of glass. -To calculate and analyse energy and mass balance of the process. - To determine experimentally crystallization stability of the glass and nucleation and crystallization curves.

FORM 2

1) Course teacher: Jelena Macan, assoc. Prof.	
2) Name of the course: COMPOSITE MATERIALS	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. to relate individual elements of physics, chemistry and engineering into a wider understanding of materials; 2. to explain the connection between structure and properties of composite materials and its use in designing new materials; 3. to plan and perform experiments; 4. to interpret experimental results; 5. to prepare laboratory reports; 6. to write a seminary paper on a given subject.	1. to relate four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues; 2. to describe various kinds of materials and technologies for their production; 3. to analyze materials by means of available laboratory equipment; 4. to independently solve problems in production and application of materials, using chemical and physical techniques as well as instrumental methods of material analysis; 5. to apply appropriate analytical methods and models for computational problem solving; 6. to present the results of their work in both written and oral form.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Polymer matrix composites	To define polymer matrices and their uses. To describe the cure of thermoset resins. To explain the advantages and disadvantages of plastomeric matrices.	Listing the types of polymer matrices and their uses. Description of the cure of thermoset resins. Listing the advantages and disadvantages of plastomeric matrices.

FORM 2

1) Course teacher: Prof.Nevenka Vrbos,Ph.D		
2. Fillers and interphase	To define types of fillers and their action on matrix through the interphase. To describe the influence of surface modification of fillers on properties of composites. To explain the factors that promote the links between the matrix and the filler.	Listing the types of fillers and explaining their influence on the matrix. Naming the ways fillers' surface can be modified. Defining the factors that promote the links between the matrix and the filler.
3. Polymer nanocomposites and production of polymer composites	To define methods of nanocomposite production. To define procedures for production of polymer composites. To summarize criteria for selecting a suitable production process.	Description of nanocomposite production methods. Description of a procedure for production of polymer composites. Selecting the production process for a type of composite material.
4. Structure of inorganic materials	To define crystal lattices of metals, alloys and ceramics. To define crystal lattice defects. To diagram phase transformations of metals and alloys.	Description of crystal structures. Listing the types of crystal lattice defects. Sketching the equilibrium phase diagram of an alloy and describing its crystallization from the melt.
5. Metal and ceramic matrix composites	To define types and applications of metal and ceramic matrix composites. To describe types of fillers and their interaction with metal and ceramic matrices. To define toughening mechanisms in ceramic composites. To define production methods for metal and ceramic composites.	Listing the types and applications of metal and ceramic matrix composites. Listing the types of fillers and their interaction with metal and ceramic matrices. Explaining the toughening mechanisms in ceramic composites. Describing the production methods for metal and ceramic composites.

FORM 2

2) Name of the course: CEMENT COMPOSITE ADMIXTURES	
3) Study programme (undergraduate, graduate): graduate 2.(1.)th term	
4) Course status: optional	
5) Expected learning outcomes: 1. Combine existing chemistry knowledge with the structure of new materials presented in the course; 2. Create the motivation for further learning on the subject matter.	**6) Learning outcomes at the level of the study programme:** 1. Point out the structure, properties and use of cement supplements; 2. Learn more about different types of additives.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1.CEMENT COMPOSITE ADMIXTURES	- Knowledge of additive distribution modes; - Understanding the influence of additives on cement hydration process.	- ability to differentiate between different additives (accelerators, retarders, superplasticizes, aerates etc.); - examination:impact of additives on increased compressive strengths.

FORM 2

1) Course teacher: prof.dr.sc. Emi Govorčin Basjić

2) Name of the course: Processing of polymers

3) Study programme (graduate): Material Science and Engineering

4) Status of the course:Elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Distinguish the procedure of polymer materials processing 2. Design the structure and properties of polymer materials in processing 3. Relation between the type and structure of polymer and structure and properties of the finished product 4. Predict the relationship between the characteristics of the material and thermal process 5. Analyse the thermal and energy balance of polymer processing	1.Apply gained knowledge from structure design to obtain the desired properties of polymer materials in processing 2. Apply gained knowledge about the thermal properties of materials important for the analysis of thermal processes in the processing 3. Ability to apply gained knowledge about processing parameters of materials for the determination of processing parameters

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Processing of polymer materials	Distinguish the basic procedure of polymer materials processing	
2. Extrusion	Explain the extrusion as a most common procedure in polymer materials processing	Report of laboratory exercise of preparation of polymer materials by extrusion
3. Moulding	Explain the moulding process of polymer materials	Report of laboratory exercise of moulding of polymer materials

FORM 2

4. Thermoforming	Distinguish the basic procedure of industrial implementation of the thermoforming process	
5. Reinforced plastic	Distinguish the procedure of designing reinforced duromer and thermoplastic materials	
6. Cellular materials	Distinguish the procedure of designing cellular materials	
7. Thermal process in processing	Distinguish types of heat transfer processes in polymer processing	
8. Thermal and energy balance of polymer processing	Analyse the thermal and energy balance of polymer processing	Report of laboratory exercise in the field of extruder processing parameters

FORM 2

1) Course teacher: **Prof. Sanja Lučić Blagojević, Ph.D.**
2) Name of the course: **Polymer nanocomposites**
3) Study programme (undergraduate, graduate): **Graduate programme   Material science and engineering**
4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To relate knowledge of polymer materials engineering with surface and interfaces engineering in multiphase polymer systems. 2. To apply knowledge of the structure, properties, production of polymer nanocomposites. 3. To acquire knowledge on the application of polymer nanocomposites as advanced materials. 4. To acquire knowledge on selection techniques and methods for the characterization of multiphase systems and quality control of the product. 5. To analyze and synthesize scientific knowledge about the structure, preparation, properties and application of polymer nanocomposites on the experimental example and present it in oral form.	**6) Learning outcomes at the level of the study programme:** 1. Understanding scientific principles important for chemistry and materials engineering. 2. Understanding of the four basic elements of chemistry and engineering materials: structure, properties, production and use of materials. 3. Deepening of knowledge about advanced polymer materials. 4. Ability to apply techniques and methods of characterization of materials. 5. Ability of effective work and the presentation of the work in written and oral form.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Differences between micro and nanocomposites	- to apply knowledge of surfaces and interfaces engineering in polymer	- explain the theory of adhesion (adsorption and chemisorption) at the

	composite systems - to analyze the differences in morphology and properties between micro and nanocomposites	interface of polymer / filler - explain and relate the impact of the filler particles size on the interface size, morphology and fraction of polymer in interphase layer
2. Nanofillers (carbon nanotubes, layered nanofillers, equi-axed nanofillers, quantum dots)	- to analyze and apply the role of chemistry and materials engineering in the synthesis of nanofillers - to choose nanofiller for a particular purpose depending on its structure and morphology - to understand the principles of chemical and physical surface modification of nanofiller	- describe the processes of synthesis of particular nano-filler - explain the relationship between structure and properties of nanofiller - explain surface modification of the nanofillers and define its advantages and disadvantages
3. Preparation of polymer nanocomposites	- to identify the optimal parameters of the preparation processes - to apply knowledge of thermodynamics in nanocomposite preparation processes - to link knowledge about polymer materials and processing	- explain the methodology of specific preparation process and specify their advantages and disadvantages - explain the role of entropy and enthalpy contributions in processes of nanocomposites preparation - identify key factors (structure of polymers and fillers, process parameters) that affect the morphology and structure of nanocomposites
	- to analyze the factors that affect the achievement of the advanced properties - to analyze and apply the mechanisms of nanofiller influence on predicting the properties of the polymeric nanocomposites	- define the impact of the fillers characteristics and surface modifications on the properties of polymer nanocomposites - explain the mechanisms of filler influence on the properties of nanocomposites (mechanical, thermal,

		electrical, optical, dimensional stability, gas permeability)

FORM 2

1) Course teachers: Prof. Mirela Leskovac, PhD	
2) Name of the course: Additives for polymer materials	
3) Study programme (undergraduate, graduate): graduate Material Science and Engineering	
4) Status of the course: optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Acquire the basic knowledge in the field of applications of various additives in the polymer processing to make the polymers easy to process and for changing the properties of the final product. 2. Analyze and conclude about the chemical, structural, performance additives for polymeric materials in relation to the application. 3. Acquire skills in the work in the laboratory in the field of the analysis methods and applications ways of the chemical compounds in the polymer processing. 4. Use various analysis methods to assess the properties and quality of the finished material.	**6) Learning outcomes at the level of the study programme:** 1. Explain, connect and apply basic thermodynamic principles to select the appropriate additives for polymeric materials. 2. Integrate knowledge and apply appropriate methodology to different types of additives to obtain polymeric materials with improved performance. 3. Manage and plan production processes and modification of polymer materials and products and demonstrate skills in the laboratory. 4. Ability of independent or team work in the laboratory and the presentation of a work in written and oral form. 5. Identify and resolve complex problems in the field of polymer engineering materials.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Polymer additives, their role and classification.	- Acquire knowledge about different important polymer additives and explain principles of their action, properties and application as well ecological and economical impacts.	- Specify and classify basic types of additives and explain the role of used additives for polymers.

2. Modifiers of physical properties; action mechanism, classification, properties and application.	- Acquire insight to defining appropriate modifiers of polymer physical properties.	- Measure and analyze the results of determining the surface properties of the additive using the pendant drop method. - Analyse the correlation between properties and applications of chosen additives. - Identify and analyse the influence of additives on the thermal stability of polymer materials. - Evaluate the effect of additives on the flammability properties - Limited oxygen index (LOI). - Identify and analyze the influence of additives on the oxidative stability of polymer materials; determination of oxidation induction time, OIT and oxidation induction temperature, OIT*. - Explain the influence of plasticizers on the polymer material properties and to evaluate the plasticizers efficiency as well the influence on the polymer surface properties (study of plasticizers migration). - Interpret obtained results and present the results in laboratory report.
3. Additives that have a protecting effect against polymer aging and degradation; action mechanism, classification, properties and application.	- Acquire insight to defining appropriate additives that have a protecting effect against polymer aging and degradation.	
4. Effects of chemically and physically active media, effect of ionizing radiations, mechanical and thermal degradation.	- Acquire insight to defining effects of different active media.	
5. Methods used to incorporate additives into polymer matrices. Ecological aspects of application of additives for polymer materials and their products. Technical trends and new market requests.	- Explain and propose appropriate methods to incorporate additives into polymer matrices.	

FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD
2) Name of the course: Packaging Polymer Materials
3) Study programme (undergraduate, graduate): graduate
4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. acquiring, understanding and analysing of knowledge about polymer packaging function, product-packaging relation, properties of polymer materials for food products 2. acquiring, understanding and analysing of knowledge related to polymer products processing technologies 3. ability to apply gained knowledge in materials production processes and quality control, and in their improvement 4. ability of self-presentation and interpretation of laboratory results in written and oral form 5. the recognition of the need for, and an ability to engage in life long learning	1. application of scientific principles underlying chemistry and chemical engineering on materials, their structure, properties, processing and performance 2. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form 3. awareness of the impact of material science and engineering solutions on society in a social, economic and environmental context 4. the ability to use the techniques, skills and modern engineering tools necessary for engineering practice 5. the ability of selecting appropriate methods and analysis equipment related to production and use of materials and critical results analysis

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Type of packaging materials	- to learn function of packaging - to identify packaging labels - to acquire knowledge about production and consumption	- to explain classifications of packaging - to distinguish main types of packaging materials - to explain what type of packaging material is used

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FORM 2

1) Course teacher: Associated professor Danijela Ašperger, Ph.D.		for specific product
2. The properties and characteristics of packaging materials	- to define mechanical, thermal and chemical properties - to acquire knowledge about barrier properties - to acquire knowledge about packaging materials quality control and food health safety	- to explain effect of mechanical forces and atmospheric conditions on packaging - to explain how barrier properties effect quality of packed food - to explain food health safety regulations
3. Polymer materials for packaging	- to identify chemistry of polymers - ability to understand influence of chemical composition and structure on properties of packaging	- to distinguish the main types of polymers used as packaging material - to explain structure-properties relation of polymers
4. Layered packaging materials	- to gain knowledge about multilayer materials - to define role of each layer in such material - to define “smart” packaging	- to explain main types of multi-layered material - to explain influence of different materials on packed product - to explain sensors in “smart” packaging
5. Technological processing and design	- to learn the technology of polymer packaging production; extrusion, blow-moulding, thermoforming - to learn production and processing costs	- to distinguish different polymer processing techniques - to explain production costs of packaging materials
6. Disposal and recycling of packaging materials	- to indicate the technology processes of recycling -to define generation, collection and transport of waste polymer packaging	- to explain each type of technologies for various polymer materials - to explain the stream of waste, systems build for the transport and collection

FORM 2

2) Name of the course: Nondestructive methods of chemical analysis in art and archaeology, Applied Chemistry

3) Study programme (undergraduate, graduate): undergraduate (1st year, 1st semester, mag. ing. cheming.)

4) Status of the course: optional

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. Proper interpretation adopted theoretical knowledge related to methods of instrumental analysis and principles of instruments and procedural knowledge and skills related to practical performance measurement. 2. Explain the connection between basic knowledge in the application of instrumental analysis of artistic artifacts and artifacts of historical importance. 3. The ability for autonomously practice on the analysis of real samples (from sampling to interpretation of results) in the laboratory for instrumental analysis of non-destructive methods and further autonomously study having a positive attitude about the need for the development of professional competencies. 4. Integrate the acquired knowledge and apply them in problem solving and decision making in the restoration and conservation practice.	1. Ability to apply basic knowledge of the natural sciences in practice, especially in solving problems based on qualitative or quantitative information. 2. Numerical reasoning, numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units. 3. Competence presentation materials related to the case study (oral and written) professional audience. 4. Monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation there of. 5. Interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory. 6. Conduct risk assessments concerning the use of chemical substances and laboratory procedures. 7 Skills in planning and time management, and the ability to work autonomously. 8. Study skills and competences needed for continuing professional development.

7) Teaching units with the corresponding learning outcomes and evaluation

criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introduction to the role of analytical chemistry and the role of the analyst with the scientific and technical aspects in education of restorers-conservators. Tasks of laboratories, laboratory techniques and methods of sampling and sample preparation in the restoration and conservation purposes. Introducing approach artifacts of artistic and historical importance made of different materials	- Use, combine and compare different methods of sampling, micro-sampling, non-destructive sampling *in situ* for different artifacts. - Use, implement and choose different methods of transport, preparation and storage of samples for different artifacts to the analysis in the laboratory and/or *in situ*.	- Define, describe, classify and apply methods of sampling and sample preparation for different artifacts.
2. Instrumental methods of analysis with a focus on micro-destructive and non-destructive methods	- Adopt and define theoretical knowledge related to methods of instrumental analysis (spectrometry (PIXE, PIGE, RBS, FTIR, etc.), electroanalytical, thermochemical, instrumental separation methods, photographic and microbiological methods), and the principles of individual methods, and procedural knowledge and skills related to practical performance measurement, connect basic knowledge and newly acquired knowledge in the course of instrumental methods, identify the strengths and limitations of individual methods.	- Define, describe, classify, apply, identify and choose adequate instrumental analytical method for analysis different artifact.
3. Laboratory exercises	- Practice on the instruments (alone or in a small group) according to the curriculum of exercises on real samples. - Operate/use programs related to the work of the instrument.	- Concisely describe the experimental work - aim, methods, and results. - Autonomously interpretation the results in laboratory report.

	- Apply the statistical processing of numerical data and their graphical presentation. - Ability to record experimental data and write reports autonomously.	

FORM 2

1) Course teacher: prof.dr.sc. Emi Govorčin Basjić	
2) Name of the course: Polymer blends	
3) Study programme (graduate (1st and 2nd year): Material Science and Engineering	
4) Status of the course: Elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Relate relationship between structure and properties of multiphase polymer systems and its effect on their application 2. Apply the criteria for the design and design a multiphase polymer systems 3. Distinguish multiphase polymer systems based on their miscibility 4. Characterize and / or identify multiphase polymer systems using various techniques	**6) Learning outcomes at the level of the study programme:** 1. Knowledge and understanding of the four major elements of material science and engineering: structure, properties, processing and performance of materials 2. Ability to apply gained knowledge in materials production processes and quality control 3. Ability to select and apply appropriate analytical methods and equipment for materials production and performance control and to analyze the results critically. 4. Ability to analyze materials using various instrumental techniques of analysis

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Polymer blends	-The acquisition of basic knowledge of polymer blends, their development and miscibility	
2. Miscibility of polymer blends	-Distinguish the polymer blends considering on the miscibility of polymer blends. - The acquisition of knowledge about the major	

	reasons for blending more polymers - Select the parameters important for the design of polymer blends	
3. Methods of polymer blends preparation and blending	– Select the methods of polymer blend preparation -Ability for individual blending of polymer blends	Report of laboratory exercise of polymer blends blending in extruder and Brabender mixer
4.Moulding of polymer blends	Ability for individual moulding of polymer blends	Report of laboratory exercise of polymer blends moulding, moulding in mould and injection moulding.
5. Effect of morphology of polymers on miscibility and properties of polymer blends	-Assess the miscibility of components in polymer system -Examine the influence of morphology of components in the blend on the miscibility and application of polymer blends	
6.Modification of interface in immiscible polymer blends	-Select of procedure of polymer blends compatibilization - Distinguish the type of compatibilizers and their influence on compatibilisation	
7. Determination of structure of polymer blends	Application of different techniques for characterization of polymer blends	Report of laboratory exercise of polymer blends characterization by DSC, DMA and TGA techniques

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FORM 2

1) Course teacher: Ivica Gusić	
2) Name of the course: Introduction to Mathematical Methods in Engineering	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. distinguish various types of partial differential equations and their physical interpretations 2. interpret boundary and initial conditions r 3. use Fourier series to solve suitable partial differential equations. 4. adopt the notion of logistic equation and its role in modelling processes. 5. interpret two-dimensional dynamical system and its solving. 6. use the corresponding procedure in Mathematica or Matlab.	**6) Learning outcomes at the level of the study programme:** 1. adopt the role of partial differential equations in engineering. 2. adopt the role of dynamical systems in engineering

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Introductory lesson	- describe analogy between engineering problems and corresponding mathematical models - describe extension of ordinary differential equations to partial differential equations and to systems of ordinary differential equations	- interpret the dynamic of change of an entity in time by the corresponding ordinary differential equation - interpret the dynamic of change of two entities in time by the corresponding system of ordinary differential equations

FORM 2

2. Basic partial differential equations	-- adopt the notion of partial differential equation, as well as its boundary and initial conditions - distinguish elliptic, parabolic and hyperbolic partial differential equations	-- recognize if a given differential equation is ordinary or partial - determine if the given equation is elliptic, parabolic or hyperbolic
3. Fourier expansion	- determine problem of representation a periodic function as a sumo f basic periodic functions sin and cos - distinguish Taylor's and Fourier's expansions	- determine the Fourier expansion of a given periodic function (even periodic, odd periodic)
4. One-dimensional wave equation	-define the problem of string vibration and its variants - write down the differential equation of vibrating string as well as the corresponding boundary and initial conditions - write down the solution of the problem of string vibration and interpret role of the Fourier expansion	-solve a given wave equation - approximately solve a given wave equation
5. two-dimensional wave equation	-define the problem of membrane vibration and its variants - write down the differential equation of vibrating membrane as well as the corresponding boundary and initial conditions - write down the solution of the problem of membrane vibration and interpret the role of the Fourier expansion	- interpret the analogy of string vibration and membrane vibration -solve a given two-dimensional wave equation - approximately solve a given two-dimensional wave equation
6. Heat equation	-define the problem of heat conducting and its variants - write down the differential	-solve a given heat equation - approximately solve a given heat equation

	equation of heat conducting as well as the corresponding boundary and initial conditions - write down the solution of the problem of heat conducting and interpret the role of the Fourier expansion	
7. Introduction to dynamical systems. Exponential and logistic equation.	- define the problem of dynamic of change o fan entity in time, and write down the corresponding differential equation - define the exponential and the logistic equation, as well as the circumstances of their appearing	- solve given exponential equation and interpret the solution - solve given logistic equation and interpret the solution
8. Two-dimensional dynamical systems. Examples of linear systems.	- define the problem of dynamic of change of two entities in time, and write down the corresponding system of differential equations - write down and interpret basics of dynamical systems: autonomy, trajectories, fixed points, phase portrait	- solve given linear dynamical system and interpret the solution - graph the trajectories of given dynamical system
9. Classification of two-dimensional linear systems	- recognize linear dynamical systems - classify two-dimensional linear systems in terms of the corresponding matrices	- determine type of given two-dimensional linear system - solve given two-dimensional linear system and interpret the solution
10-11. Nonlinear systems important in applications	- distinguish between linear and nonlinear dynamical systems, and interpret their disparity in modelling engineering problems -Write down some basic nonlinear two-dimensional	- interpret given nonlinear two-dimensional dynamical system, as well as its parameters - determine and interpret fixed points of given

	dynamical systems	dynamical system
12-13. Graphical solving of nonlinear systems	-describe the procedure of graphic solving nonlinear two-dimensional dynamical system - analyse the role of parameters and initial point	- graphically solve given dynamical system - analyse the solution with respect to parameters
14. Three-dimensional dynamical systems. Lorentz equations (optional content)		
15. Chaos (optional content)		

FORM 2

1) Course teacher: Marijana Kraljić Roković, PhD, assistant professor
2) Name of the course: Conducting polymers-synthetic metals
3) Study programme (undergraduate, graduate): graduated
4) Status of the course: elected

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):	**6) Learning outcomes at the level of the study programme:**
1. recognise scientific and technological roll and importance of electrically conducting polymers 2. apply modern analytical and physico-chemical methods in development and application of conducting polymers 3. define principles of conductivity in order to prepare and improve conducting polymer properties 4. distinguish polymer structures that belong to the group of conducting polymers	1. the ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering; 2. ability to solve problems in production and performance of materials with the aid of chemical and physical techniques and instrumental methods of materials analysis; 3. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Electrical conductivity	-give an example of conducting polymers -distinguish the difference between conventional polymer and conducting polymer -describe intrinsic conductivity and doping process of conducting polymers	-sketch conducting polymer structure -explain intrinsic conductivity mechanism and doping process of conducting polymers -recognise structure of electronically and ionically conducting polymer -demonstrate the method that

	-distinguish the difference between electronically conducting polymers and ionically conducting polymers -explain the method that can be used to determine electrical conductivity of conducting polymers	can be used to determine electrical conductivity of conducting polymers
2. Synthesis of conducting polymers	-explain synthesis mechanism of conducting polymers -memorise the most important synthesis procedures and monomers -explain nucleation mechanism of conducting polymer at metal support	-illustrate synthesis mechanism of conducting polymers -state the most important synthesis procedures and monomers -illustrate nucleation mechanism of conducting polymer at metal support
3. Properties and application of conducting polymers	-relate structure, properties, processing, and performance of conducting polymers and apply this knowledge on practical issues -explain influence of counter-ion and substituent on conducting polymer properties -outline morphological properties of conductive polymers -explain electrochromic properties of conducting polymers -predict applications of conducting polymers in	-give an example of counter-ion and substituent influence on conducting polymer properties -relate morphological properties and application of conducting polymers -relate electrochromic properties and application of conducting properties -select appropriate techniques for investigations of conducting polymers

	various fields of technologies -describe techniques used in the field of conducting polymers -describe methods of preparation and properties of nanostructurised conductng polymers	

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FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD	
2) Name of the course: Elastomers	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to understand the specific principles in the chemistry of elastomers 2. acquisition, understanding and analyzing the basic knowledge related to the technologies in rubber industry 3. acquisition of the ability to understand the methods of process control and quality control of rubber 4. ability of self presentation and interpretation of laboratory results in written and oral form	**6) Learning outcomes at the level of the study programme:** 1. application of scientific principles, which include basic principles of chemistry and chemical engineering, on materials, their structure and properties 2. knowledge of various kinds of materials and technologies for their production, 3. skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards;

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Elastomer properties. Introduction to vulcanization processes. Basic vulcanization systems.	- to define the terms elastomer and elasticity; the basic properties of elastomers - to define the term vulcanization, the basic components of vulcanization systems - to define the terms unvulcanized and vulcanized rubber	- to define the term elasticity and elastomers -to explain the vulcanization processes, to recognize the needed components in vulcanization system -to distinguish unvulcanized and vulcanized rubber
2. Natural and synthetic rubber.	- the acquisition of knowledge about natural rubber collection and its	- to explain the collection of natural rubber and the processes for the production

1) Course teacher: Prof.Nevenka Vrbos,Ph.D

	properties - to define the reactions and principles for obtaining of synthetic rubber - to define the properties of rubber and the area of its application in everyday life	of the synthetic rubber -to define the various areas of the rubber application
3. Specific rubber types and their application.	- to indicate the different rubber types: polybutadiene, polyisoprene, polychloroprene, fluorine, nitrile, polysulfide rubber. - to indicate the areas for application of specific rubber types	- to define and explain the differences between the different types of rubbers -to define the areas of application for specific rubber types
4. Rubber processing and products design.	- to indicate the basic principles for rubber processing; rubber products design. - to indicate the specific rubber products and the methods for the properties characterization and quality determination	-to distinguish the principles for processing and design of various rubber products. -to explain the basic methods for rubber quality determination
5. Degradation of rubber.	- to acquire the knowledge about the rubber degradation	-to define the basic changes in rubber materials caused by degradation - to define the structure-properties relationship in rubber materials caused by degradation processes
6. Recycling of rubber.	- acquisition of knowledge about the basic methods for rubber recycling as well as the products made of recycled rubber	-to define the basic methods for rubber regeneration - to explain the methods for rubber pretreatment before recycling process - to define the main products made of recycled rubber

FORM 2

2) Name of the course: CEMENT COMPOSITE ADMIXTURES		
3) Study programme (undergraduate, graduate): graduate 2.(1.)th term		
4) Course status: optional		
5) Expected learning outcomes: 1. Combine existing chemistry knowledge with the structure of new materials presented in the course; 2. Create the motivation for further learning on the subject matter.	**6) Learning outcomes at the level of the study programme:** 1. Point out the structure, properties and use of cement supplements; 2. Learn more about different types of additives.	
7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1.CEMENT COMPOSITE ADMIXTURES	- Knowledge of additive distribution modes; - Understanding the influence of additives on cement hydration process.	- ability to differentiate between different additives (accelerators, retarders, superplasticizes, aerates etc.); - examination:impact of additives on increased compressive strengths.

FORM 2

1) Course teacher: prof. dr. sc. Stanislav Kurajica	
2) Name of the course: X-ray diffraction in materials engineering	
3) Study programme (undergraduate, graduate): Materials science and engineering (graduate)	
4) Status of the course: Electional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Understanding of the characteristics of the crystalline state, the importance of crystal structure for mechanical, physical and other properties of material, and the application of knowledge on understanding of structure and behavior of various materials. 2. Understanding the principles of emergence of X-rays, diffraction and working of diffractometer. 3. Accepting the skills necessary for work with diffractometer, conducting of experiment and for analysis of data obtained by measurement. 4. Ability for identification of crystal phases in powder sample, conducting of qualitative analysis, characterization of solid solution and microstructure. 5. Ability for critical thinking and capability for cognition and solving of problems in the area of X-ray diffraction and structural characterization. 6. Ability of applying the knowledge of mathematics and structure and properties of materials. 7. Ability to work in multidisciplinary team and communication skills.	**6) Learning outcomes at the level of the study programme:** 1. Application of scientific principles underlying chemistry, physics and chemical engineering on materials, their structure, properties, processing and performance. 2. Understanding and integration of four major elements of materials science and engineering: structure, properties, processing, and performance of materials, and application of this knowledge on practical issues. 3. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 4. The ability to choose and apply appropriate analytical methods and models for computational problem solving, including the use of commercial databases and analytical and modeling programs. 5. Ability to apply gained knowledge in materials production processes and quality control, and in their improvement. 6. The ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering. 7. Capability for further learning.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Theoretical basis of crystallography and X-ray diffraction	Knowledge of damaging effects of ionizing radiation to humans. Understanding of principles of radiation protection. Knowledge of measurement units used for ionizing radiation. Application of safety rules for work with ionizing radiation. Understanding of crystalline nature of matter. Distinguishing between chemical bonds and knowing principles of arrangement of atoms, ions or molecules into crystal lattice. Understanding of the terms unit cell and crystal structure. Distinguishing between crystal systems and Bravais lattices. Knowing, recognizing and distinguishing of symmetry elements. Perceiving of crystallographic planes. Determination of Miller indices. Understanding of the concept of point and space group. Understanding the principle of X-rays formation. Knowing of nature and properties of X-rays. Distinguishing between continuous and characteristic spectrum. Knowing of X-rays detection methods. Knowing and understanding of phenomena occurring in interaction of X-rays diffraction with material. Interpretation of diffraction	Describe biological effect of ionizing radiation. List principles of radiation protection. Define important measurement units used dor ionizing radiation and dose limits. List security rules for work with ionizing radiation. Distinguish between crystal and amorphous state. Describe characteristics of crystalline state. List chemical bonds and the differences between them. Describe principles of arrangements of atoms, ions or molecules in crystal lattice. Define unit cell. List and describe crystal systems and Bravais latices. Distinguish, perceive and describe symmetry elements. Describe and perceive crystallographic planes and state corresponding Miller indices. Distinguish and explain terms point group and space group. Explain principle of X-rays Describe the nature and properties of X-rays. Distinguishing between continuous and characteristic spectrum. Describe X-ray detection methods. Describe phenomena occurring in interaction of X-rays with material. Define diffraction. Describe the geometry of diffraction. Define terms connected with

	geometry. Interpretation and application of Braggs law. Understanding of term reciprocal lattice. Understanding of dependence of diffraction lines intensity on crystal structure. Interpretation of scattering on electron, atom, unit cell and crystal. Understanding of the term structure factor.	X-ray diffraction. Describe Von Laue's approach. Specify and explain Bragg's law. Explain term reciprocal lattice. Explain the dependence of diffraction lines intensity on crystal structure. Describe scattering of radiation at electron, atom, unit cell and crystall. Define and describe structure factor.
2. Practical applications of diffraction methods	Distinguishing between different methods of X-ray diffraction analysis. Interpretation of diffraction on single crystal. Knowing of the parts of apparatus for powder X-ray diffraction. Application of the apparatus for powder X-ray diffraction. Knowing and application of sample preparation methods. Knowing and understanding of kinds and sorces of error in the diffraction data. Interpretation of data for the identification of crystal phases using ICDD database. The application of computer analysis for the interpretation of data, methods of atomatic identification of crystal phases. Interpretation of data for the determination of lattice parameters, solid solution characterization, determination of crystallite size and microstrain measurements. Interpretation of data for	Differentiate and explain different methods of conducting of X-ray diffraction experiment. Interpretation of measurement data obtained uding X-ray diffraction on single crystal. Description of working principle of powder X-ray diffraction apparatus. List and description of parts of powder X-ray diffraction apparatus. Describe and apply methods of sample preparation. State and explain most common sorces of measurement errors. Conduct measurement and interpret measurement data of qualitative analysis of single- and multi-component system using ICDD database. Apply computer analysis for interpretation of data and identification of crystal phases. Conduct measurement and interpret measurement data for the determination of

	quantitative analysis. The application of methods of outer and internal standards, addition, reference intensity ratio method. Knowing of the basics of structure solving and indexing of reflexes Understanding of Rietveld refinement method. Perceiving of factors influencing diffraction pattern. Application of Rietveld refinement on simple example. Perceiving of wide applicability of X-ray diffraction in materials engineering. Reproduction of various areas of application.	lattice parameters and characterization of solid solution. Conduct measurement and interpret measurement data for the determination of crystallite size and micro-strain measurement. Conduct measurement and interpret measurement data for the qualitative analysis. Discern, apply and analyze data obtained using various quantitative analysis methods. Conduct measurement and interpret measurement data for the determination of crystal structure and indexing. Describe Rietveld method Define factors influencing the appearance of diffraction pattern. Apply Rietveld refinement for simple sample. State the areas of application of X-ray diffraction in materials engineering. Describe important areas of application.

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FORM 2

1) Course teacher: Prof. dr. sc. Sanja Lučić Blagojević and Prof. dr. sc. Stanislav Kurajica	
2) Name of the course: Introduction to nanotechnology	
3) Study programme (undergraduate, graduate): Materials science and engineering and Chemical engineering (graduate)	
4) Status of the course: Electional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. The ability to explain certain properties of materials and to understand the reasons for change of properties occurring on nano-scale. 2. The understanding of ideas, concepts and techniques in the field of nanotechnology and the ability of their critical judgment. 3. Distinguishing of top-down and bottom-up methods of nanofabrication, the understanding of these methods and being able to perceive their advantages and disadvantages. 4. The ability to analyze the purpose and to apply knowledge of materials science and engineering in nanotechnology 5. To explain connection between structure and properties of nano-objects and integrated nano-systems. 6. To describe different methods of characterization on nano-scale and to know principles of these methods and perceive their advantages and idsadvantages. 7. To perceive momentary limitations in the development of nanomaterials and ethical doubts appearing in the field of nanotechnology. 8. To demonstrate communication skills, ability of critical thinking and cognition of the need for further learning.	**6) Learning outcomes at the level of the study programme:** Chemical Engineering 1. The ability to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods. 2. The ability to understand and apply specific chemical engineering skills such as mass and energy balances, single and multi-component thermodynamics, fluid mechanics, heat and mass transfer operations, process economics, process design, process safety and process design. 3. The ability to communicate effectively. 4. The ability to understand social importance and the role of engineering as well as the importance of the highest ethical standards in professional work. 5. The ability to identify, define and solve complex engineering problems with relevant methodologies and available program packages. 6. The recognition of the need for, and an ability to engage in life long learning. Materials science and engineering 1. Knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials. 2. Knowledge on various kinds of materials. 3. An introductionary knowledge to advanced materials and technologies.

	4. Ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work both in written and oral form. 5. Awareness of the impact of material science and engineering solutions on society in the social, economic and environmental context. 6. Recognition of the need for further learning. 7. Ability to develop understanding of the techniques and methods applied in production, and quality control, as well as understanding of their limitations. 8. Ability to identify, formulate and solve material science and engineering problems.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The properties and characterization of nanomaterials	- Knowing of terms in the field of nanoscience and nanotechnology. - The understanding of the properties of materials (especially physical, mechanical, chemical, optical, electrical and magnetic) and causes for the change of properties on nano-scale. - Knowing of the principles of typical methods for the characterization of nanomaterials (especially transmission and scanning electron microscope as well as scanning tunneling microscope and atomic force microscope. - The combination of knowledge on structure and properties on nano-scale with the aim of perceiving of application potential of	- The listing of typical characteristics of nanotechnology. - Explaining terms typical for nanomaterials and nanotechnologies - Explaining terms connected to various properties of materials and connection between structure and properties of materials. - Explaining reasons for changing of certain properties on nano-scale - Describing operating principles of typical methods of nanomaterials characterization. - The listing of constrains, advantages and disanvantages of certain methods. - Describing preparation of samples for certain methods of characterization.

	nanomaterials and nanoproducts.	
2. Nanofabrication, manufacturing, trends and applications of nanomaterials	- The differentiation between top-down and bottom-up methods of nanofabrication. - Understanding of principles of these methods, controlling factors and limitations (especially lithography, dip-pen nanolithography, crystallization, sol-gel method, chemical vapor deposition, self-assembly and nanomanipulation. - Understanding of ideas, concepts, techniques and trends in the field of nanotechnology (especially in electronics, medicine, materials engineering and environmental protection) and the ability of their critical judgment. - Perceiving of ethical doubts appearing in the field of nanotechnology and the ability to discuss on them.	- List the methods of manufacturing - List and explain classification of nanomanufacturing methods - List most important nanomanufacturing methods from each category. - Describe the most important methods, advantages, disadvantages, limitations, controlling factors. - List some nanoproducts already at the market. - List main areas of investigation in nanotechnology, aims of these investigation, assumtions they are based on and the purpose of aimed nanoproducts. - List some of the potential risks associated with nanotechnology.
3. Nanoobjekti	- Recognition of the role of materials science and engineering in synthesis of nanoobjects. - Connection between structure and properties of nanoobjects. - Understanding of principles of chemical and physical modifications of nanoobjects surfaces.	- Describe synthesis processes of certain nanoobjects. - Explain connection between structure and properties of nanoobjects and specificities in relation to bulk materials. - Explain and analyse the manners of sertain nanoobjects modification.
4. Selected nanotechnologies (nanobiotechnology, nanoelectronics, polymer nanocomposites)	- The recognition of scientific and technological acheivements realised in the area of nanotechnology. - The insight in realized and potential acheivements in certain areas of	- Explain the purpose and define contribution of certain areas of nanotechnology and give examples from literature. - Describe examples in certain areas of

	nanotechnology. - The analysis of the purpose of nanoobjects for certain applications in integrated systems.	nanotechnology. - Explain the purpose of nanoobjects and other components of integrated systems.

University of Zagreb
Faculty of Chemical
Engineering and Technology

FORM 2

1) Course teacher: prof.dr.sc.Emi Govorčin Bajsić
prof.dr.sc. Sanja Lučić Blagojević
prof.dr.sc. Mirela Leskovac

2) Name of the course: Exercises from materials engineering

3) Study programme (graduate): Material Science and Engineering

4) Status of the course:Mandatory

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Application of scientific principles of chemistry and material engineering in the given topics.
2. Understanding and application dependencies between elements of materials engineering (method of preparation, characterization, properties, applications) for different types of materials (ceramic, polymer, metal).
3. Gaining experience in independent work in a safe manner in the chemical and / or physical laboratory.
4. Analysis of materials using various techniques and methods, depending on the given topic.
5. Critically analysis of own results, connection of these results with current literature findings and draw conclusions about obtained results.

6) Learning outcomes at the level of the study programme:

1. Knowledge and understanding of scientific principles important for chemistry and chemical engineering
2. Knowledge and understanding of four major elements of materials science and engineering: structure, properties, processing, and performance of materials.
3. Skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards
4. Ability to analyze materials using chemical and physical techniques and various instrumental methods of analysis.
5. Ability to select and apply appropriate analytical methods and equipment for materials processing and performance control and to analyze the results critically.
6. Ability to function effectively an individual and to present the work in written and oral form.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Review of the scientific and / or technical literature knowledge	-Recognize the basic scientific principles relevant to a given topic - Select methods for material preparation - Select instrumental technique of characterization important for material application - interpretation the results of given topic audience	-Analysis and synthesis of the literature findings related to the topic - Understanding the advantages and disadvantages of the methods for materials preparation - Explain the methodology and data analyses for individual techniques of physical and/ or chemical analysis – Prepare the oral presentation with defined aim, literature knowledge and draw the flow diagram for a given research topic
2. Experimental implementation of a task	Skills required for independent work in the chemical and / or physical laboratory	- Individual preparation and/or characterization of materials depending on the given topic
3. Final analysis and presentation of results	-Critically analysis of individual results - conclude based on the results of analysis and literature knowledge - Presentation of own results and conclusions in oral and written form	-Understanding and application of relationship between preparation and / or structure and / or properties and / or the application of a given material - Relate the results of own work and literature knowledge - Make the presentation of the tasks, research results and conclusions in in writing form and orally present them to students and teachers

FORM 2

1) Course teacher: Associated professor Danijela Ašperger, Ph.D.

2) Name of the course:

Quality management, Material Science and Engineering

3) Study programme (undergraduate, graduate): undergraduate

(2nd year, 3rd semester, mag. ing. cheming.)

4) Status of the course: required

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. Interpret the quality assurance system over the quality of the analytical/production process, products and services.
2. Ability of autonomously creation, establishment, implementation, control and improve the quality of the analytical/production process, products and services.
3. Ability to make decision, creates new ideas, apply knowledge in practice and operate some processes based on the results of quality assurance and application of standards.
4. Ability of autonomously work and presenting the results in an interdisciplinary team, and establishing good communication with people who are not experts, but with the ability to work in an international context.

6) Learning outcomes at the level of the study programme:

1. Ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form.
2. Ability to use diverse methods of communication with the engineering community, industry, business and with society at large.
3. Commitment to professional ethics and responsibilities, as well as the norms of engineering practice with the knowledge for capability for further learning.
4. Awareness of the impact of material science and engineering solutions on society in a social, economic and environmental context.
5. The capacity for critical and independent analysis of the results, identifying, defining and solving problems in the field of chemistry and material engineering.

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	Learning outcomes	Evaluation criteria
1. Definition, planning, implementing and documenting quality assurance programs, elements of the quality system.	- interpret the quality assurance system over the quality of the analytical/production process, products and services,	- plan and optimize the experiment, - identify sources of error of the measurement system and remove them,

FORM 2

2. The importance of adequate measurement process in ensuring the quality of processes and products, as well as planning, standardization and optimization of the measurement system.	- ability of autonomously creation, establishment, implementation, control and improve the quality of the analytical/production process, products and services, - ability to make decision, creates new ideas, apply knowledge in practice and operate some processes based on the results of quality assurance and application of standards, - ability of autonomously work and presenting the results in an interdisciplinary team, and establishing good communication with people who are not experts, but with the ability to work in an international context.	- estimate impact of measurement uncertainty on the results and on this basis to make decisions, - plan, design, evaluate and interpret validation of the measurement system, - apply, construct/compose, explain and interpret Ishikawa diagrams, Pareto diagram, methods of process analysis and diagrams of dissipation to improve the quality of the analytical / production processes, products and services, - interpret experimental results.
3. Internal and external quality assessment, collaborative studies, reference materials, independent assessment of the quality system certification and accreditation.		
4. Project management, planning, quality, time and cost of the project, and cost-benefit analysis. Standards and standardization.		

FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD

2) Name of the course: Polymer Science and Technology

3) Study programme (undergraduate, graduate): graduate

4) Status of the course: elective

5) Expected learning outcomes at the level of the course (4-10 learning outcomes):

1. to collect the basic knowledge about main polymerization reactions
2. to describe and understand the the types of homogeneous and heterogeneous polymerization processes
3. to understand the relationship structure – properties of polymer materials
4. to learn important technologies for polymer processing
5. to understand the knowledge related the polymer degradation and stability
6. to describe and understand the biopolymers

6) Learning outcomes at the level of the study programme:

1. application of scientific principles underlying chemistry and chemical engineering on materials, their structure, properties, processing and performance
2. ability to function effectively as an individual or as a member of a multi-disciplinary team, and to present the work in both written and oral form;
3. skills necessary for running chemical and physical laboratories, selection and preparation of adequate laboratory equipment and organization of laboratory work according to standards;
4. an introductionary knowledge to advanced materials and technologies

7) Teaching units with the corresponding learning outcomes and evaluation criteria

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The main polymerization reactions	- to define mechanisms of polymerizations: chain, step, ionic polymerisation - to define the main types of synthesized polymers (polyolefines, polyesters, polyamides..) - acquisition of knowledge and understanding influence of catalysts type, temperature and time on formation of	-to interpret polymerization processes -to distinguish different type of polymerizations -to recognize the type of condition and type of structure that is formed

	polymer chain structure and of molecular weight	
2. The homogeneous and heterogeneous polymerization processes	- to indicate the type of polymerizations: in bulk, in solution, emulsion, suspension… - to indicate the different reactors for polymerizations	-to define the polymerization types: advantages and disadvantages - to explain the differences between the reactors
3. the relationship structure – properties of polymer materials	- to explain the importance of the structure – properties relationship - to indicate the importance of creating a different structure of polymer chain	- to define and explain properties of polymers in relations with applications -to distinguish the importance of different polymer chain structures
4. Technologies for polymer processing	- to indicate basic type of polymer processing technologies: extrusion, injection, pressing, blowing… - to indicate the main equipment and conditions for polymer processing	-to define type of polymer processing -to define main processing equipment for polymers - to explain effect of conditions of production on the properties
5. Polymer degradation and stability	- to indicate the properties of polymer materials - acquisition of knowledge about the main types of polymer degradation and their mechanism - to indicate the mechanism of stabilization processes	-to define various properties of polymer: chemical properties, mechanical, physical … - to define degradation processes of polymers: photodegradation, thermodegradation, oxidative degradation… - to explain the importance of polymer stabilization
6. Biopolymers	- acquisition of knowledge about biopolymers -to indicate biodegradation processes	-to define biopolymers and biodegradation - to explain sustainable development: advantages and disadvantages of biopolymers

FORM 2