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

FORM 2

	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	

University of Zagreb
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FORM 2

1) Course teacher: dr. sc. Vesna Volovšek, full 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 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. 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 lows and the lows of conservation of linear and angular momentum - to establish the equation of motion	- Explaining physical concept - Mathematical formulation of physical problem - Describing the model and its restrictions

	- to explain the relationship between different dynamic 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), Stjepan Milardović (Associate Professor), Ivana Steinberg (Assistant Professor)

2) Name of the course: General and Inorganic 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. 6. To identify stable and less stable (unstable) oxidation states of elements. 7. To conclude on the stability of hydrides and oxides of elements based on their electronegativity. 8. To conclude on the redox behaviour of the substance in elemental form based on standard reduction potential. 9. To conclude on the reactivity of elements in elemental form based their ionization energy. 10. To identify the compound based on its chemical formula and to write a chemical formula of inorganic compound based on its name.	1. The ability to apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems. 2. Organizational and planning abilities necessary to perform simple experiments with available laboratory equipment and devices. 3. Recognition of the need for further learning. 4. The ability to work both independently and in multidisciplinary teams. 5. Learning skills and competences required for further vocational training.

7) Teaching units with the corresponding learning outcomes and evaluation

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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 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.	- 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 configuration of neutral atoms and ions
2. Chemical bonds; Molecular shape and structure;	The student will identify 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

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3. Gases, liquids and solids; Reaction thermodynamics; Physical and chemical equilibria; Chemical kinetics; Electrochemistry; Nuclear chemistry	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 reaction and estimate its direction. The student will compare the acids and bases. The student will explain the different types of radioactive decay.	- 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 (electrochemical reaction) reaction - to calculate and analyse the chemical equilibrium constant - to calculate the pH of the solution - to write and balance the nuclear reaction equation
4. Inorganic chemistry Periodicity of chemical properties (electronegativity, ionization energy, electron affinity, oxidation numbers); The general atomic and physical properties of molecular hydrogen (preparation in industrial and laboratory scale); The 1st group of the elements (alkaline earth metals); The 2nd group of the elements (alkali metals)	The student will explain the periodic trends of the first ionization energy, electronegativity and atomic radii. The student will predict oxidation and reduction trends in periodic table based on standard reduction potentials. The student will compare reactivity of atomic and molecular hydrogen. The student will propose a suitable method for the hydrogen preparation (reduction of water, acid or base) based on standard reduction potential of the metal. The student will explain the typical reactions of alkali and alkaline earth metals.	- to argue the questions based on application of theoretical principles -to solve the worked examples applying theoretical knowledge

FORM 2

The 13th group of the elements (boron group) The general chemical properties of the boron group of the elements. Properties of compounds (oxidation states in the range –3, –1, 0, +1, +2) The 14th group of the elements (carbon group) The general chemical properties of the carbon group of the elements. Preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO_2.	The student will recognize stable and less stable oxidation states based on electron configuration of elements. The student will conclude on stability of hydrides and oxides (13th group of elements) based on electronegativity data The student will explain the reactivity of aluminum in elemental state. The student will explain the preparation of polyborates by condensation of $B(OH)_3$. The student will conclude on reactivity in elemental states based on ionization energy. The student will analyse properties of compounds containing the elements in oxidation states –4,–2 and 0 (14th group of elements). The student will explain hydrolysis of tin and lead compounds. The student will explain the preparation of silicates by condensation of $Si(OH)_4$.	- to argue the questions based on application of theoretical principles -to solve the worked examples applying theoretical knowledge
The elements of 15th group (nitrogen group) The general chemical properties of the nitrogen group of the elements. The change of electronegativity along the group, properties of compounds (oxidation states in the range –3, –1, 0, +1, +3, +5). Preparation, use and	The student will conclude on the stability of hydro-oxides, -sulfides, -selenides and tellurides based on electronegativity. The student will conclude on the bond order and magnetic properties of oxygen, oxides, peroxides and superoxides using MO diagram	- to argue the questions based on application of theoretical principles -to solve the worked examples applying theoretical knowledge

chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth. The elements of 16th group (chalcogens) The general chemical properties of the chalcogens group of the elements. The properties of compounds (oxidation states in the range –2, –1, 0, +2, +3, +4,+6).	The student will conclude on the molecular and atomic oxygen reactivity. The student will compare the reactivity, acid-base stability and redox properties of ammonia, phosphine, arsine and bismuthine. The student will conclude on the bond order of N_2O, NO, NO_2, N_2O_3, N_2O_5 using MO diagram of nitrogen and oxygen.	
The elements of 17th group (the halogens) The general chemical properties of the halogen elements, physical and chemical trends along the group. Oxoacids and their salts (preparation and properties). The elements of 18th group (noble gases) Atomic and physical properties of noble gases. Preparation, production and use. Xenon compounds and derivatives of other noble gases.	The student will analyse the stability and bond order in diatomic halogen molecules using MO diagram. The student will conclude on the hydrohalous and hypohalous acid strength based on electronegativity. The student will draw the Lewis structure of halogen oxoacid and predict its strength.	- to argue the questions based on application of theoretical principles -to solve the worked examples applying theoretical knowledge
The properties of metals	The student will compare the stability of complexes of 3d, 4d and 5d elements. The student will analyse quantitatively electron absorption spectra of various	- to argue the questions based on application of theoretical principles -to solve the worked examples applying theoretical knowledge

	dn systems. The student will describe the magnetic properties of metallic complexes and their colour.	

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

FORM 2

		- 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. Vesna Volovšek, full 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): 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 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

	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. Veljko Filipan
2) Name of the course: BASICS OF MECHANICAL ENGINEERING
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 basic rules and standards in engineering graphical communication 2. apply principles of engineering mechanics to simple systems 3. define connection between loads, stresses and strains 4. differentiate basic loading form on simple structure elements 5. interpret basic materials properties and testing methods …..	1. apply fundamental principles for identification and description of simple engineering problems 2. define and solve simple engineering problems with relevant methodologies and available program packages 3. apply basic information and communication technologies 4. learning skills and competences required for further vocational training 5. the ability to collect information from various sources …..

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. basics of engineering graphics	- apply basic rules and standards in engineering graphical communication - apply graphical symbols for process schemes	- sketch orthogonal projections of simple equipment parts on the basis of isometric view - mark dimensions of simple elements on technical sketch - draw simple process scheme with some particular elements
2. fundamentals of applied mechanics	- apply fundamental principles of engineering	- simplify the connections between bodies in simple

	mechanics to analysis of simple elements - define equilibria conditions of simple engineering problems - understand stresses and strains caused by different loads - differentiate calculated, real and allowable stress and strain	multibody systems and define the equilibria conditions - generate diagrams of internal forces of simple beams - calculate stress and strains in rods under different simple loads -calculate thermal stresses of simple rods - determine dimensions of simple loaded elements
3. basic properties of engineering materials and testing methods	- explain interconnections between internal structure and properties and the application of engineering materials - differentiate mechanical, chemical, physical and technological properties of materials and their testing methods	- sketch and explain diagrams for static and dynamic testing methods results - use real properties of materials for dimensioning of simple structure elements - interpret mechanical, chemical, physical and technological properties of materials

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FORM 2

1) Course teacher: Šime Ukić	
2) Name of the course: Analytical Chemistry	
3) Study programme (undergraduate, graduate): undergraduate study – Chemical Engineering	
4) Status of the course: obligatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. To define analytical system in accordance with technological process. 2. To relate principles of chemical equilibrium with methodology of analysis in technological process. 3. To apply methods of selective separation of inorganic anions and cations in chemical engineering. 4. To apply methods of gravimetric analysis in chemical engineering. 5. To apply methods of volumetric analysis in chemical engineering.	**6) Learning outcomes at the level of the study programme:** 1. To apply basic knowledge from natural science in identification and description of simple engineering problems. 2. To plan simple experiments by applying available laboratory equipment. 3. To analyse technological process.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Analytical system in chemical engineering	- To define analytical system in accordance with technological process.	- To define analytical method. - To recognize a mode for determination of analytical signal and to obtain analytical result - To express significant digits. - To differentiate method's accuracy and precision

FORM 2

2. Qualitative chemical analysis of technological processes	- To relate principles of chemical equilibrium with methodology of analysis in technological process. - To apply methods of selective separation of inorganic anions and cations in chemical engineering.	- To compute solution's pH value. - To compute conditions of inorganic salts precipitation. - To compute conditions of complex formation - To compute redox potential - To plan systematic analysis of cations and anions - To compute possibility for executing the planed systematic analysis - To apply principles of dissolution of inorganic salts
3. Quantitative chemical analysis of technological processes	- To relate principles of chemical equilibrium with methodology of analysis in technological process. - To apply methods of gravimetric analysis in chemical engineering. - To apply methods of volumetric analysis in chemical engineering.	- To plan the steps in gravimetric analysis - To differentiate types of sediments' contamination and how to prevent or remove the contamination - To differentiate properties of sediment related to the particle size - To compute result in gravimetric analysis - To plan steps in volumetric analysis - To differentiate end-point and equivalence point in titration - To select indicator and method for detection of titration end-point. - To compute result of

		volumetric analysis - To compute all points on titration curve

FORM 2

English language I (basic course)
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

FORM 2

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

English language II (advanced course)
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.

FORM 2

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

FORM 2

	- 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

FORM 2

	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: Prof. dr. sc. Veljko Filipan	
2) Name of the course: ENGINEERING THERMODYNAMICS	
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. apply basic thermodynamics laws for thermodynamic calculations of processes with ideal and real working media 2. apply graphical representation in defining and analysis of thermodynamic processes 3. use tables and diagrams with thermodynamic properties of some particular real working media applied in real processes and devices 4. define energy indicators of thermodynamic processes and devices working in heating and cooling modes	**6) Learning outcomes at the level of the study programme:** 1. apply fundamental principles for identification and description of simple engineering problems 2. define and solve simple engineering problems with relevant methodologies and available program packages 3. chose and apply appropriate mathematical/numerical methods for problem solving 4. apply basic information and communication technologies 5. learning skills and competences required for further vocational training

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. basic thermodynamic laws and thermodynamic quantities	- understand basic terms and definitions in engineering thermodynamics - differentiate thermodynamic quantities such as enthalpy entropy, heat, energy and work - connect the 1st and the 2nd law of thermodynamic - differentiate thermodynamic processes according to the direction of the process	- define basic thermodynamic state quantities and thermal quantities - explain analytical expressions of thermodynamic laws - calculate mechanical work due to volume changes and technical work - define basic cyclic processes

FORM 2

2. processes with ideal working media	- define basic processes with ideal gasses; represent them in diagrams - define processes of compression and expansion; differentiate real and ideal ones - calculate reversible and irreversible thermodynamic processes with ideal gas - know achievable cyclic processes	- reproduce and explain the equation of state for ideal and real working media - sketch p,v T,s and h,s diagrams of basic processes with ideal gasses - generate diagrams of achievable cyclic processes - calculate thermodynamic properties and energy performance of particular cyclic processes
3. processes with real working media	- explain thermal properties and changes in real working media - use charts and tables with properties of real working media in calculation of basic process	- sketch and explain diagrams of basic thermodynamic processes with real working media - use h,d diagram for defining real processes with wet air

FORM 2

1) Course teacher: Marica Ivanković; Jelena Macan	
2) Name of the course: Physical chemistry I	
3) Study programme (undergraduate, graduate): undergraduate, Chemical 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 apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems 2. To perform simple experiments with available laboratory equipments and devices 3. To perform mathematical calculations 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: Prof. Bruno Zelić, PhD	
2) Name of the course: Mass and Energy Balances	
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 apply basic principles of mass and energy conservation on physical, chemical and biochemical processes 2. to define process space, system borders, and inlet and outlet process parameters 3. to differentiate steady-state and non steady-state, closed and open process 4. to develop mass and energy balances of case studies 5. to construct simple process schemes of chemical and related industrial processes	**6) Learning outcomes at the level of the study programme:** 1. to apply and optimize chemical and related industrial processes 2. to apply methodology of chemical engineering for process development 3. to manage and schedule processes 4. to manage and schedule time 5. to apply mathematical methods, models and techniques for solving of case studies

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Mass balance of physical processes	- to apply basic principle of mass conservation on physical processes - to define process space, system borders, and inlet and outlet process parameters - to develop mass balance of case studies - to construct simple schemes of chemical and related industrial processes	- construct process scheme for case study and identify inlet and outlet process streams and parameters - determine the base for calculation - apply the principle of mass conservation and develop mass balances for case study - solve resulting system of independent linear equations
2. Mass balance of chemical	- to apply basic principle of	- construct process scheme

processes	mass conservation on chemical and biochemical processes - to define process space, system borders, and inlet and outlet process parameters - to develop mass balance of case studies - to construct simple schemes of chemical and related industrial processes	for case study and identify inlet and outlet process streams and parameters - determine the base for calculation - apply the principle of mass conservation and develop mass balances for case study - solve resulting system of independent linear equations
3. Mass balances of processes in multiple process units with and without recirculation	- to apply basic principle of mass conservation on physical, chemical and biochemical processes - to define process space, system borders, and inlet and outlet process parameters - to develop mass balance of case studies - to construct simple schemes of chemical and related industrial processes	- construct process scheme for case study and identify inlet and outlet process streams and parameters - determine the base for calculation - apply the principle of mass conservation and develop mass balances for case study - solve resulting system of independent linear equations
4. Energy balance of physical processes	- to apply basic principles of mass and energy conservation on physical processes - to define process space, system borders, and inlet and outlet process parameters - to differentiate steady-state and non steady-state, closed and open process - to develop mass and energy balances of case studies - to construct simple process schemes of chemical and related industrial processes	- construct process scheme for case study and identify inlet and outlet process streams and parameters - determine the base for calculation and standard conditions - seek literature data needed for calculation of energy balances - apply the principle of mass and energy conservation and develop mass and energy balances for case study - solve resulting system of independent linear equations

FORM 2

5. Energy balance of chemical processes	- to apply basic principles of mass and energy conservation on chemical processes - to define process space, system borders, and inlet and outlet process parameters - to differentiate steady-state and non steady-state, closed and open process - to develop mass and energy balances of case studies - to construct simple process schemes of chemical and related industrial processes	- construct process scheme for case study and identify inlet and outlet process streams and parameters - determine the base for calculation and standard conditions - seek literature data needed for calculation of energy balances - apply the principle of mass and energy conservation and develop mass and energy balances for case study - solve resulting system of independent linear equations

FORM 2

1) Course teacher: Asoc. Prof. Jasna Prlić Kardum PhD	
2) Name of the course: Transport phenomena	
3) Study programme (undergraduate, graduate): Undergraduate, Chemical Engineering	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Understand the principles and lows of transport phenomena (momentum, heat and mass transfers) 2. Understand the principles of transport phenomena applied to fluid motions 3. Understand and apply the basic equations at macroscopic level depending on mechanism of momentum, heat and mass transfers 4.The ability to use the methodology of dimension analysis 5. Apply analogy between momentum, heat and mass transfer to define transport coefficients	**6) Learning outcomes at the level of the study programme:** 1. The ability to apply chemical engineering methodology. 2. The ability to apply fundamental engineering knowledge to interpret experimental results. 3. The ability to choose and apply mathematical and numerical methods for solving transport phenomena problems 4. The ability to use experimental results to gather information for engineering designs. 5. The ability to understand the impact of engineering solutions on the surrounding context.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Introduction and basics concepts of transport phenomena	-Define terms for understanding and describing the process of momentum, energy and mass	-Define fluid concepts, continuum hypothesis and nature of fluid flows -Explain the mechanisms of fluid transport -Define the basic equations which explain transport phenomena -Describe driving and drag

		forces and transport coefficients -Identify Newton and non-Newton's fluids and rheological equations which describe their behavior
2. Momentum transport	-Express conservation lows for fluid in motions -Recognize laminar and turbulent fluid flow -Clarify boundary layer theory -Apply dimensional analysis for defining pressure loss in fluids -Use Moody diagram -Define different cases of momentum transport and apply specific equations	-Describe conservation lows and apply them to calculate the pump power -Compare laminar and turbulent flow -Analyze hydrodynamic boundary layer structure -Draft velocity distributions in tube for laminar and turbulent flow -Calculate fluid velocity -Define ratio between average and maximal velocity -Derive Darcy Weisbach equation -Define friction factor by using Moody diagram -Estimate drag force of flow around body, in a mixing tank or through packed bed -Define dimensionless numbers
3. Heat transport	-Define and recognize mechanisms of heat transfer -Apply equations for stationary and non stationary conduction heat transfer -Express analytical solutions for cooling/heating in finitely and semi-infinitely bodies -Define influence of hydrodynamic conditions on	-Distinguish and explain difference between conduction, convection and radiation -Analysis of conduction heat transfer trough bodies of different geometry -Determine area of heat transfer and driving force for heat transfer

	convection heat transfer -Review different methods for obtaining convective heat transfer coefficient -Describe heat transfer for different geometries -Describe nature and basic lows for radiation -Discuss heat transfer during phase changes	-Define influence of hydrodynamic conditions on heat transfer coefficient - -Define mining of different dimensionless number and correlation equations -Analyze lows to explain radiation -Calculate overall heat transfer coefficient in phase-change systems
4. Mass transport	-Define basic concepts in mass transport -Distinguish steady mass transfer cases -Define diffusion boundary layer and convective mass transfer coefficient	-Distinguish and explain difference between diffusion and convection -Distinguish Fick and Stephan low -Explain mass transport and individual and overall mass transfer coefficients in two phase systems
5. Analogies between heat, mass and momentum, transfer	-Describe the principles of analogy	-List and explain differences between analogies -Apply analogies to calculate mass or heat transfer coefficients

1) Course teacher: Krešimir Košutić (Full Professor)	
2) Name of the course: Physical Chemistry II	
3) Study programme (undergraduate, graduate): The undergraduate study of Chemical Engineering	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 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	**6) Learning outcomes at the level of the study programme:** 1. the ability to apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems, 2. organizational and planning abilities necessary to perform simple experiments with available laboratory equipment and devices, 3. the ability to apply scientific methods in process analysis and modelling and in product design, 4. the ability to work both independently and in multidisciplinary teams, 5. the ability to understand social importance and role of engineering and the importance of the highest ethical standards in professional work 6. the ability to chose and apply appropriate mathematical/numerical methods for problem solving

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 of constant pressure and temperature using the Gibbs energy, derive thermodynamic equilibrium constant - Describe the response of	-Compute equilibrium constant in the examples of homogeneous and heterogeneous equilibrium - Analyze and interpret the Haber Bosch synthesis of ammonia, optimize process parameters of pressure and

	equilibria to temperature and pressure - Derive van't Hoff reaction isobars - Describe the homogeneous and heterogeneous chemical equilibria	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 -Derive an Ostwald's law - Define the concept of activity - Explain the Debye-Hückel theory of strong electrolytes Describe the equilibrium of electrode-solution	- An experimental determine the conductivity of strong and weak electrolytes - An experimental determine electrode potential, electromotive force (EMF) and Hittorf's number - Demonstrate skill calculating molar conductivity, degree of dissociation, activity coefficients, electrode

	-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	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 transition state (activated complex) - Define the basic concepts of catalytic reaction Prepare and make a laboratory experiments: Decomposition of H_2O_2,	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

FORM 2

	Inversion of saharose - Calculate measurement data and interpret the results of the experiment, and write a lab reports	

FORM 2

1) Course teacher: Assoc. Prof. Jasna Prlić Kardum, PhD Assoc. Prof. Gordana Matijašić, PhD	
2) Name of the course: Fluid Mechanics	
3) Study programme (undergraduate, graduate): Undergraduate, Chemical Engineering	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. The ability to identify and describe rheological behavior of fluids. 2. Apply fundamental knowledge of fluid statics and dynamics for compressible and incompressible fluids. 3. The ability to choose and apply adequate equipment for fluid transport. 4. Apply fundamental principles of fluid mechanics to solve problem s in two-phase flow regime.	**6) Learning outcomes at the level of the study programme:** 1. The ability to apply chemical engineering methodology. 2. The ability to apply basics of fundamental engineering knowledge. 3. To analyze complex chemical engineering problems. 4. The ability to apply methodology of theoretical interpretation of experimental results.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Rheological behavior of fluids	- Define the basic terms of fluid mechanics - Identify rheological behavior of fluid	- Define fluid concepts, continuum hypothesis and properties of fluid - Name the forces in fluids - Sketch rheological diagrams - Identify rheological equations depending on rheological behavior
2. Fluid statics	- Define the basic terms of fluid statics	- Describe hydrostatic pressure -List and describe the mode

FORM 2

	- Describe Euler equation - Understand the manometer principle of operations	of hydrostatic manometers - Calculate a liquid level in a tank
3. Dynamics of incompressible fluids	- Understand the principles of continuity momentum and energy as applied to fluid motions - Describe flow equations - Understand laws for non-newtonian fluids	- Recognize and describe these principles written in form of mathematical equations - Calculate velocity distribution of Couette flow - Define meaning of Navier-Stocks equation - Apply Navier-Stocks equation to analyze problems - Define flow, velocity distribution and pressure drop for non-newtonian fluid flow
4. Fluid transport	- Define fluid motions through narrow orifices - List and classify types of pumps - Compute the branched pipeline	- Define cavitation conditions - Derive equation and calculate the required time for tank discharge - Outline characteristics of pumps - Explain selection criteria and pump design - Calculate the pressure drop and the pump power for fluid transport through the branched pipeline
5. Dynamics of compressible flow	- Describe characteristics of compressible fluids - Explain isothermal flow of ideal gas in horizontal pipe	- Apply conservation laws for compressible fluids - Evaluate head loss for the isothermal fluid flow
6. Dynamics of heterogeneous system	- Analyze characteristics of two-phase flow - Categorize homogenous and heterogeneous systems	- Predict and describe flow regimes in gas-liquid system - Evaluate pressure drop for two-phase flow - Describe hydraulic transport

		of heterogeneous systems - Define factors affecting rheological behavior - Explain pneumatic transport

FORM 2

1) Course teacher: Prof. Felicita Briški, PhD.

2) Name of the course: Environmental Protection

3) Study programme - undergraduate: Chemical 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 explain the composition and basic processes in the atmosphere, hydrosphere and lithosphere, and the impact of different types of pollution on the abiotic and biotic resources 2. to apply the principles of mathematics, physics, chemistry and microbiology in monitoring and analyzing the distribution of contaminants in water, soil and air 3. to explain and compare the systems of water treatment and wastewater treatment, explain the systems for processing solid waste and treatment of harmful gases 4. to outline a simple scheme of the process of processing pollutants 5. to apply laws and regulations related to environmental protection	1. to identify the problems in the environment (water, soil, air) and apply theoretical knowledge to solve problems 2. to apply methodology of chemical engineering and environmental engineering in solving problems in the environment and in industry 3. to choose simple processes and process equipment for treatment the pollutants in waste streams 4. to assess how designed process affects on the global environment 5. to analyze the impact of new technologies, environmental concerns and public opinion on the legislation

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Ecosystems, flow of substances in the environment, population and demographic changes	- to describe the flow of matter and energy in the biomes - to explain the transport and transformation of substances in the environment - to analyze the rate of	- illustrate the flow of matter and energy in the biomes and state the energy efficiency - describe and sketch the cycles of substances in the environment - solve the growth rate and

FORM 2

	growth of the human population in different parts of the world	the doubling time of the human population applying differential equation
2. Classification of water, pollution of water sources, waste water and waste water treatment	- to distinguish the characteristics of rivers, lakes and oceans - to select and apply appropriate process to remove contaminants from groundwater - to analyze the chemical composition of the waste water - to select and apply appropriate process and process equipment for waste water treatment	- explain the importance of the thermocline and label it on the diagram of vertical profile of the water column - describe mechanisms of filtration and adsorption, and write mathematical expressions that describe the adsorption isotherm - explain the composition of waste water and purpose of waste water treatment, and point out the consequences of discharge of untreated water in the receivers - outline the process of wastewater treatment and set up the mass balance
3. The soil as a natural phenomenon, the use of soil and soil pollution, solid waste management	- to describe the formation of soil and identify types of soils - to analyze the impact of over-use of pesticides - to explain and differentiate the procedures for solid waste management	- explain factors which influence the formation of soil - summarize the mechanisms of distribution of pesticides in the environment, and procedure of their removal from the environment - select the appropriate disposal procedure for a given type of solid waste
4. The atmosphere and the movement of air masses, the sources of air pollution and the removal of harmful gases	- to describe the layers of the atmosphere and explain the movement of air masses - to identify the sources of pollution in the atmosphere, and specify process equipment for treatment of flue gas	- indicate the chemical composition of the atmosphere, and sketch the layers of atmosphere - explain the difference between stationary and mobile sources of pollution, and select the procedures to prevent emissions
5. Noise, light pollution, thermal pollution and	- to indicate the sources and methods for noise	- calculate the overall noise level for a given group of

radioactive contamination	measurement, and explain the implementation of noise protection - to identify sources of light pollution and choose the proper illumination - to analyze the sources of pollution of thermal power plants, and select the treatment processes for removal of pollution - to describe the application of radioactive substances, and differentiate types of radioactive waste - to explain the methods of disposal of radioactive waste	machines, and select equipment for noise reduction - describe the impact of light pollution on the environment, and define the type of illumination for a given space - describe the impact of untreated pollutants from power plants on the environment, and apply proper process for removal of thermal pollution - list the sources of radio-active radiation, sketch and describe the types of radiation and their impact on environment - select a disposal procedure for a given radioactive waste

University of Zagreb
Faculty of Chemical
Engineering and Technology

FORM 2

1) Course teacher: Associate Prof. Dragana Mutavdžić Pavlović

2) Name of the course: Process and instrumental analysis

3) Study programme (undergraduate, graduate): undergraduate, 2nd year

4) Status of the course: required

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

Before this course, it is expected a systematized fundamental knowledge of courses Physics, General and Inorganic Chemistry, Analytical Chemistry, Organic Chemistry and Physical Chemistry.

1. Properly interpreted adopted theoretical knowledge related to instrumental methods of analysis and principles of instruments and the procedural knowledge and practical skills related to performance of measurement.

2. Explain the connection between the fundamental knowledge with their application in instrumental and process analysis.

3. Compare, interpret and explain the results obtained from the analytical process.

4. Integrate acquired knowledge and apply them in solving the problem as well as in the making decision in analytical practice and in process analysis.

5. Evaluate, compare, select, recommend and conclude what is the best analytical method for a given real problem.

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

1. The ability to apply basic knowledge of the natural sciences in identifying and describing the engineering problems.

2. The ability to organize and plan experiments using the laboratory equipment and devices.

3. The ability of individual work and ability to work in teams.

4. Skill presentation of research results related to the content of the study (in writing and orally).

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Introduction: Fundamentals of process analytics. Basic principles of instrumental	- list the calibration procedures and define the differences between them and the difference in their application,	- apply previously acquired knowledge to select the calibration procedure,

analysis. Signal processing in the analysis. Validation. Calibration procedures (standard addition method, the method of external standard, internal standard method).	- argue the need for calibration procedures, - describe the signal to noise ratio,	depending on the given topics and applied instrumental technique
2. Instrumental analytical methods	- apply the theoretical knowledge in relation to the methods of instrumental analysis (spectrometry, thermal and electroanalytical analysis, instrumental methods of separation) and the principles of instruments operation and procedural knowledge and skills related to practical performance of measurement, - distinguish the techniques of instrumental analysis, - identify and distinguish the relative methods from absolute method, - connect basic with new knowledge gained in the course of instrumental methods, - identify the advantages and limitations of various methods	- define which of instrumental methods used depending on the type of sample and the proportion of the analyte, - classify the spectrometric and electroanalytical methods; the differences between the individual methods within the same group, - distinguish signals excitation and response depending on the methods of instrumental analysis, - apply the skills of computation depending on instrumental methods
3. Automation in instrumental analysis. Process analysis and process analyzers.	- connect adopted and the theoretical knowledge of instrumental analysis methods and principles of instruments with the basic settings of process analysis,	- connect the acquired theoretical knowledge of instrumental techniques with their application in process analysis,
4. Laboratory exercises	- use laboratory equipment (alone or in a small group) according to the curriculum of exercises, - operate/use with appropriate programs related to the work at the instruments, - apply the basics of statistical analysis of numerical data and their graphical presentation, - systematically and independently record and document the appropriate measurement size and produce a report after completion of the analysis	- practical work on the instruments, - independent processing of the measurement results and graphical representation of results, - writing the experimental data and making the laboratory reports

FORM 2

English language I (basic course)

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
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 II (advanced course)

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:

FORM 2

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
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

University of Zagreb
Faculty of Chemical
Engineering and Technology

FKITMCMXIX

FORM 2

1) Course teacher: Dr. Marijana Hranjec, associate professor

2) Name of the course: Organic 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. Analyzing and drawing the correct structure of compounds with carbon, bonding in organic molecules and structures of molecules in space 2. Using the stereochemistry knowledge in analyzing mechanisms in organic chemistry 3. Define and identify the main types of organic reactions and explain the basic reaction mechanisms with the recognition of reactive intermediates in the reaction 4. Identify the functional groups in the molecules,to define the class of compounds and to apply the IUPAC rules for naming of organic compounds 5. Carry out the standard preparative procedures used for the preparation of simple organic compounds 6. Propose and devise the most likely reaction method for new molecules that are not given as examples in class	1. To apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems. 2. To adopt organizational and planning abilities necessary to perform simple experiments with available laboratory equipment and devices. 3. To work both independently and in multidisciplinary teams 4. To identify, define and solve simple engineering problems with relevant methodologies and available program packages. 5. To adopt learning skills and competences required for further vocational training.

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Carbon compounds and chemical bonds, classes of compounds, a division of reactions in organic chemistry. Alkanes and cycloalkanes. Conformational	- to identify class of compounds, chemical bonding and hybridization - draw the correct structural representations of alkanes and cycloalkanes, alkenes,	- to know to classify the default compounds according to the groups of organic compounds - be able to determine the most stable conformations of

and geometric isomerism. Alkenes, dienes, polyenes, alkynes: addition reaction.	dienes, polyenes, alkynes - to use knowledge of conformational and geometric isomery to define the stereochemistry of molecules - write acceptable mechanisms for reactions of alkanes, alkenes, alkynes -to propose the most stable conformers of alkanes Newman projections - compare the stability of a variety of substituted cyclohexane rings	alkanes and cycloalkanes - apply knowledge of the stability of carbocations in addition reactions to the double bond of an alkene and diene
2. Stereochemistry: optical isomerism, constitutional isomers and stereoisomers, enantiomers and chiral molecules, (R) / (S) system, the diastereomers. Aromatic compounds. Alkyl halides. Alcohols, phenols, aryl halides, ethers, thiols.	- to use the (R) / (S) system for determining the absolute configuration of carbon achiral - properly draw of enantiomeric displays of asymmetric organic molecules - to use the knowledge of stereochemistry to distinguish various types of stereoisomers - to write acceptable mechanisms of electrophilic aromatic substitution reaction - to compare the reactivity of alkyl halides in nucleophilic substitution reactions and elimination reactions - to discuss about the difference in reactivity of alcohols, phenols and related compounds	- apply the rules of the absolute configuration determination to the new compounds with achiral carbon atom - for a given monosubstituted aromatic compound determine in which direction is directed entering of another substituent depending of the nature of substituted groups - determine the direction and the reaction mechanism of the default alkyl halide depending on the structure of the substrate and the strength of the nucleophile
3. Aldehydes and ketones; nucleophilic addition to the carbonyl group. Carboxylic acid and derivatives. Amines and related compounds with nitrogen. Heterocyclic compounds.	- to use of the organic chemistry dictionary for the carbonyl compounds, heterocycles and nitrogen compounds - draw the correct spatial structures of organic molecules containing a	- judgment about the reaction pathway of electrophilic additions on default heterocyclic compound - to conclude about the possibility of mutual translation of carboxylic acid derivatives

	carbonyl or amino group - to write acceptable transformations in nucleophilic addition reactions to the carbonyl group of aldehydes, ketones, carboxylic acids and derivatives - to compare the reactivity of the amine depending on the structure - suggest the most likely reaction method in the reactions of electrophilic additions on various heterocyclic nuclei	- to recommend preparation of a variety of substituted aromatic compounds via a diazonium salt of the corresponding amine - determine the alkalinity of certain heterocyclic nuclei depending on their heteroatom
4. Synthetic polymers. Amino acids, proteins and nucleic acids. Carbohydrates. Determination of the structure of organic compounds by spectroscopic methods.	- to use the knowledge about the types of polymerization to obtain concrete examples of synthetic polymers - to know the basic structural features of essential amino acids, proteins and nucleic acids - to become familiar with and recognize the structure of the most important carbohydrates - to become familiar with and discuss the most important methods for determining the structure of organic compounds - to compare the most important methods for determining the structure of organic compounds	- based on the acquired knowledge to suggest ways of modification structure of synthetic polymers in order to improve properties - apply and connect the knowledge about the structure of essential amino acids with the structure of a protein - to know the structure of nucleic acids - to know the structure of the basic and most important carbohydrates - to conclude and compare the application of specific methods for determining the structure of organic compounds

FORM 2

1) Course teacher: Assoc. Prof. Gordana Matijašić, PhD

2) Name of the course: Mechanical Process Engineering

3) Study programme (undergraduate, graduate): Chemical Engineering, Undergraduate

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. 2. To analyze mechanical separation processes. 3. To analyze mixing of homogenous and heterogeneous systems. 4. To analyze energy and kinetic aspects of the grinding process. 5. To conduct experiments in laboratory scale in order to estimate the parameters required for the process design.	1. The ability to apply scientific methods in process analysis and modelling and in product design. 2. Organizational and planning abilities necessary to perform simple experiments with available laboratory equipment and devices. 3. The ability to understand basic methods of characterization. 4. To analyze complex chemical engineering problems. 5. The ability to practice chemical engineering methodology in product development. 6. The ability to apply the methodology of the theoretical interpretation of experimental results. 7. The ability to work both independently and in multidisciplinary teams.

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Characterization of coarse disperse phase.	- analyze the properties of coarse disperse phase - recognize the methods of characterization of coarse disperse phase	- distinguish disperse system, disperse phase and disperse medium - define dispersity state and mixedness

	- define the mode of graphical interpretation and approximation of particle size distribution	- explain particle shape - illustrate the meaning of equivalent diameters - sketch the graphical representation of particle size distribution - explain the meaning of parameters of distribution functions through real example - apply theoretical knowledge in practical measurement
2. Mechanical separation and sedimentation	- define separation efficiency - describe sedimentation - identify inlet and outlet variables - recognize and distinguish separation equipment	- distinguish total and grade efficiency - sketch grade efficiency curve - explain separation efficiency through characteristic values - explain basics of gravitational and centrifugal sedimentation - solve the examples to estimate parameters for sedimentation basin design - apply theoretical knowledge in practical measurement - name the types of gravitational and centrifugal sedimentation equipment - illustrate inlet/outlet streams using equipment scheme - recognize the principle of sedimentation device mode - point out separation device advantages and disadvantages - identify values essential for selection of sedimentation

		equipment
3. Filtration	- describe filtration - identify inlet and outlet variables - recognize and distinguish separation equipment	- explain the basics of cake filtration and centrifugal filtration - solve the examples to estimate parameters for filter design and scale-up - apply theoretical knowledge about cake filtration in practical measurement - categorize the filtration equipment - recognize the principle of filtration device mode - illustrate inlet/outlet streams using equipment scheme - point out separation device advantages and disadvantages - identify values essential for selection of filtration equipment
4. Mixing of fluids, suspensions and powders	- define degree of mixing in homogenous and heterogeneous systems - define primary variables that determine the mixing conditions - analyze dynamic process response	- distinguish hydrodynamic regime in liquid-liquid and solid-liquid mixing - explain possible suspension states and suspending regimes - recall the scale-up rules in mixing of homogenous and heterogeneous systems - solve examples of mixing system design - apply theoretical knowledge in practical measurement - define powder types, mixture types and mixture quality

FORM 2

		- explain particle segregation and mechanisms of segregation
5. Comminution and agglomeration	- analyze energy and kinetic aspects of the grinding process - recognize and distinguish equipment for particle size reduction and enlargement - describe the modes of equipment selection	- interpret basics of fracture mechanisms - explain models for estimation of energy consumption in comminution - describe kinetics of particle size reduction - apply theoretical knowledge in practical measurement - name the types of equipment - illustrate inlet/outlet streams using equipment scheme - recognize the principle of grinding device mode - point out separation device advantages and disadvantages - identify values essential for selection of filtration equipment

FORM 2

1) Course teacher: Vesna Tomašić	
2) Name of the course: Catalysis and catalysts	
3) Study programme (undergraduate, graduate): Chemical Engineering (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. distinguish catalytic properties (activity, selectivity, stability), compare homogeneous vs. heterogeneous catalysis 2. compare the kinetics and mechanism of homogenous and heterogeneous-catalytic reactions 3. determine the difference between physical adsorption and chemisorption 4. classify the catalyst with respect to the composition and describe methods of catalyst preparation 5. propose a mechanistic kinetic expression for bimolecular reaction 6. identify the factors that affect the overall reaction rate of heterogeneous catalytic reactions 7. derive the effectiveness factor with respect to the intraparticle diffusion and interphase diffusion 8. identify different types of the experimental reactors used to determine reaction rates 9. apply the appropriate numerical and/or analytical methods to estimate parameters of kinetic models.	1. the ability to apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems, 2. the ability to work both independently and in multidisciplinary teams, 3. the ability to identify, define and solve simple engineering problems with relevant methodologies and available program packages, 4. the ability to chose and apply appropriate mathematical/numerical methods for problem solving,

FORM 2

7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
Introduction. Homogeneous catalysis: acid-base, catalysis with metal ions.	- explain the mode of action of catalysts - compare homogeneous and heterogeneous catalysts	- formulate criteria for the comparison of homogeneous and heterogeneous catalysts - identify catalytic features
Kinetics and mechanism of homogeneous catalytic reactions.	- indicate the basic features of homogeneous catalysis - classify homogeneous catalytic reactions	- explain the influence of the catalyst on the reaction kinetics and thermodynamic features - explain the catalytic effect on the activation energy and the reaction order
Heterogeneous catalysis. Physical adsorption and chemisorption. The composition and preparation of the catalyst.	- explain the theory of heterogeneous catalysis - highlight the differences between physical adsorption and chemisorption - specify different methods of preparing the catalysts	- explain the importance of chemisorption for heterogeneous catalysis - explain the influence of the synthesis parameters on the catalytic and performance properties of the catalyst
The kinetics and mechanism of heterogeneous-catalytic reactions.	- distinguish between empirical and mechanistic kinetic models - explain the Langmuir - Hinshelwoodov mechanism	- derive kinetic model for mono-molecular and bimolecular reaction - determine the effect of temperature on the rate of heterogeneous catalytic reactions
The overall reaction rate of the heterogeneous-catalytic reactions. Heat and mass transfer in catalytic reactors.	- identify the successive steps involving in the overall reaction rate of the heterogeneous catalytic reaction - compare microkinetics vs. macrokinetics	- illustrate the temperature and concentration gradients around and within the porous catalyst for the exothermic heterogeneous catalytic reaction

FORM 2

Effectiveness factors: interphase and intraphase. Experimental methods and criteria in the kinetic studies.	- describe different types of the experimental reactors used to determine the rate of reaction - explain the experimental method to investigate the influence of inter- and intraphase diffusion and determination of the reaction regime	- compare the integral and differential reactors - outline the criteria and explain the experimental methods to assess the influence of the physical processes of heat and mass transfer on the overall reaction rate
Selectivity of the catalyst.	- compare different types of selectivity - determine the influence of chemical and physical properties of the catalyst on the catalyst selectivity	- distinguish between different types of selectivity
Catalyst deactivation. Kinetics and mechanism of catalyst deactivation. Diffusion and deactivation. Selectivity and deactivation. Prevention of catalyst deactivation and catalyst regeneration.	- define the concept of the catalyst deactivation - identify possible mechanisms of catalyst deactivation - illustrate the influence of mass transfer on the rate of deactivation	- compare the kinetic models of deactivation for different mechanisms of deactivation - compare different types of the poison adsorption on the catalytic surface - explain the difference between catalyst reactivation and catalyst regeneration

FORM 2

1) Course teacher: Prof. Aleksandra Sander, PhD	
2) Name of the course: Thermal Separation processes	
3) Study programme (undergraduate, graduate): Chemical Engineering (undergraduate)	
4) Status of the course: Required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. The ability to select methods that are feasible for separation of a mixture from physical-chemical data for the compounds in the mixture. 2. The ability to understand how various parameters influence the capacity, degree of separation and energy efficiency of various separation process. 3. The ability to solve material and energy balances combined with phase equilibria for the analysis of various separation processes. 4. The ability to develop skils in solving engineering problems related to the design and performance of the separation process. 5. The ability to develop experimental skils necessary for analysis and the performance of the separation processes.	**6) Learning outcomes at the level of the study programme:** 1. Organizational and planning abilities necessary to perform simple experiments with available laboratory equipment and devices. 2. The ability to apply scientific methods in process analysis and modelling and in product design. 3. The ability to apply the methodology of the theoretical interpretation of experimental results. 4. The ability to apply fundamentals of natural sciences which are necessary for identification and description of simple engineering problems.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Heat exchangers	- identify types of heat exchangers and explain their advantages and disadvantages - decide about the fluid streams allocation - analyze heat exchanger	- distinguish different types of heat exchangers - apply theoretical knowledge in solving numerical examples - use diagrams for F-factor,

	performance - evaluate the necessary heat transfer area based on the kinetic equation - define and evaluate the driving force for the heat transfer, heat exchanger efficiency and the number of transfer units - evaluate the individual and the overall heat transfer coefficients and the pressure drop on the shell and tube sides	heat exchanger efficiency, friction factor and heat transfer factor - determine graphically and numerically heat transfer coefficients and pressure drop on the tube and shell side of heat exchangers - evaluate the performance of heat exchanger based on their own experimentally obtained results
2. Evaporation	- Identify and explain the operation of different types of evaporators - explain the boiling point elevation - solve the material and heat balances of the evaporator, and the kinetic equation for heat transfer - explain the energy saving methods - recognize differences between single and multistage evaporators	- students answers questions related to evaporators - schematically illustrate evaporator and define inlet and outlet streams - apply the linearity rule (Durhing) for determination of the boiling point elevation - use tables and diagrams necessary for the calculations - solve numerical examples using material and heat balances and kinetic equation
3. Crystallization	- define and explain different crystallization methods - explain methods for achieving supersaturation - explain mechanism and kinetic of the nucleation and crystal growth - explain the influence of process conditions on the crystallization kinetic and the granulometric properties of the crystals - solve the material and heat	- select the appropriate crystallization method based on the solubility diagrams - define the driving force (supersaturation) - distinguish different types of nucleation - schematically illustrate crystallizer and define inlet and outlet process streams - apply theoretical knowledge in solving numerical examples related to the

	balances of the crystallizer, and the kinetic equation for heat transfer - evaluate basic dimensions of the crystallizer and heat transfer coefficient	crystallization from solution
4. Drying	- definine types of moisture in the material - define drying method based on the wet material characteristic - describe heating methods - solve material and heat balances - illustrate the drying process in the humidity charts - define and explain the drying rate periods - define the moisture transfer mechanisms - explain the energy saving methods - evaluate the basic dimensions of the selected dryers	- explain humidity charts - illustrate and explain drying curves - define the controlling mechanism for mass transfer - distinguish psychometric and gravimetric methods - evaluate the mechanism of moisture transfer - evaluate basic dimensions of the fluidbed and rotary dryer
5. Distillation	- use phase equilibrium diagrams - define and explain the performance of different distillation methods - define inlet and outlet streams in the distillation column - derive the operating lines from the mass balance equations - graphically and numerically determine the number of transfer units	- distinguish different methods of distillation - evaluate the feasibility of the separation of binary mixture by distillation - distinguish zeotropes and azeotropes - schematically illustrate the distillation column with the inlet and outlet process streams - evaluate the heat consumption of the condenser and evaporator

	- analyze the influence of the feed conditions, reflux ratio and number of transfer units on the composition of distillate - define the height of the transfer unit - evaluate basic dimensions of the distillation column	- apply the McCabe-Thile and Ponchon Savaritovom method for determination of the number of transfer units - make decision about the column internals
6. Extraction	- explain the feasibility of the separation of liquid mixture by extraction - define major properties of the solvent and select the appropriate solvent for extraction - solve mass balance and kinetic equation of an extractor - define methods for liquid-liquid extraction - describe methods for increase of the specific surface area - explain the performance of different types of extractors - evaluate the mass transfer coefficient	- select the appropriate solvent based on the physicochemical properties of the phases and phase equilibrium data, taking into account the solvent recovery by means of distillation - schematically illustrate different types of extractors with the inlet and outlet process streams - illustrate the process in the phase equilibrium diagrams (ternary, distribution) - define and calculate the driving force for the mass transfer - graphically and numerically determine the number of transfer units - list the equipment for extraction
7. Absorption	- define the basics of the absorption (phase equilibrium, mass transfer) - define significant solvent properties - apply mass balance and kinetic equation - explain the methods of performing absorption	- select the appropriate solvent - apply McCabe Thile method for determination of the number of transfer units - illustrate the operating line in the equilibrium diagram for different absorption methods - perform simple calculations

	- explain NTU/HTU concept - define parameters significant for the design of the absorption column	related to the dimensioning of the absorber - determine the flooding velocity
8. Selection of the feasible separation process and the corresponding equipment	- select the feasible separation process - select the appropriate equipment	- decide about the feasibility of the selected separation process based on the physicochemical properties and the phase equilibrium - apply selection guides for different types of equipment

FORM 2

1) Course teacher: Vanja Kosar
2) Name of the course: Chemical Reactors Engineering
3) Study programme (undergraduate, graduate): Undergraduate
4) Status of the course: Active

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 process variables and parameters of chemical reactors 2. implement the kinetic models based on the physical picture of the process or conducted kinetic experiment 3. vary the reaction kinetics in homogeneous and heterogeneous systems 4. set up the mathematical models of the processes with chemical reaction in various types of reactors (kinetic and reactor model)	1. apply the methodology of chemical engineering when choosing a reactor for the implementation of certain types of reactions 2. apply mathematical numerical and / or analytical methods in estimation of the kinetic model parameters 3. apply the acquired knowledge in modeling and design of chemical reactors 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. The theory of process space and a chemical reactor	- define the chemical reactor as the basic unit of chemical processes - define the process space, system boundaries, and input and output variables of the process - define the basic division and classification of chemical reactors	- distinguish between the main types of chemical reactors - apply the basic law of material conservation and define mass balances of select process
2. The ideal reactor types and their mathematical models	- define the reactor model for batch reactor	- predict the features of a batch reactor while conducting heat and mass

	- define the reactor model for CSTR reactor - define the reactor model for plug-flow reactor	balances - predict the features of a CSTR reactor while conducting heat and mass balances - predict the features of a plug-flow reactor while conducting heat and mass balances
3. Kinetic models in homogeneous and heterogeneous systems	- define the dependence of reaction rate on temperature - define the characteristics of the kinetics of reactions in homogeneous systems - define the characteristics of the kinetics of reactions in heterogeneous systems	- vary the basic features of chemical reactions in homogeneous and heterogeneous systems - apply the Arrhenius dependence in determining the activation energy of conducted kinetic experiment
4. The main types of heterogeneous systems reactors	- reactors for implementation non-catalytic fluid - solid reactions - reactors for implementation gas- liquid reactions	- apply the core model or a model of continuous reaction kinetics when defining non-catalytic reaction fluid-solid - apply the Whitman's theory of the boundary layer during the absorption of the gas phase reactant in the liquid phase
5. Experimental methods in kinetic studies	- Define the integral method of the kinetic model parameters estimation - Define the differential method to estimate parameters of the kinetic model - Define the modified differential method (ID algorithm) to estimate parameters of the kinetic model - Define the agreement	- Apply different numerical methods to estimate parameters depending on the complexity of the reaction system (kinetic model and experimental reactor) - Critically choose the best kinetic model based on mean square deviation criteria which describes conducted kinetic experiment

	criterion of experimental data and calculated values	
6. Non-ideal flow and mixing in chemical reactors	- Residence time distribution (RTD) curves - theory - Define models of flow in chemical reactors - Define the impact of chemical reactions on the RTD curves	- Distinguish the causes of deviations from ideal flow and mixing - Experimentally determine the RTD curves - Applied axial dispersion flow model to describe the deviations from the ideal flow in tubular reactors

FORM 2

1) Course teacher: Prof. Felicita Briški, PhD.		
2) Name of the course: Environmental Ecology		
3) Study programme - undergraduate: Chemical Engineering		
4) Status of the course: optional		
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to apply the principles of industrial ecology in industrial systems 2. to calculate the flow of matter and energy for the selected production process 3. to assess the effectiveness metrics for different levels (local, national, global) 4. to choose data and sketch a simple diagram of the production system	**6) Learning outcomes at the level of the study programme:** 1. to point to the systematic approach of fitting of industrial systems in the natural environment 2. to analyze and evaluate the state of the environment 3. to use specialized tools for designing sustainable industrial system 4. to support collaboration and promote a team approach to solving an environmental problems	
7) Teaching units with the corresponding learning outcomes and evaluation criteria		
Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Environment and anthrophosphere, status of resources, and industrial systems	- explain the impact and integration of anthrophosphere in the environment and regulatory approach to pollution prevention - to identify the availability and accessibility of natural resources - to apply the principles of industrial ecology in industrial systems - to analyze the material and energy flow in the industrial system	- describe and schematically show the anthrophosphere integration in the environment - estimate availability and accessibility of a given natural resource, and evaluate its use - explain the design of the production process according to the principles of industrial ecology - evaluate the effectiveness of a given industrial process based on the material and energy productivity
2. Industrial ecosystems,	- to compare the natural and industrial metabolism and	- explain the features of

FORM 2

design and product development, and life-cycles of industrial products	define the components of the industrial ecosystem - to organize a team and implement industrial ecology tools for designing a new product / process - to apply life-cycle assessment	natural and industrial metabolism, sketch and compare an open and closed industrial system - define the team members and choose the tools to develop a given product / process - analyze the life-cycle of a given product (e.g. chemical industry, organic synthesis)
3. Corporate industrial ecology toolbox and implementation of industrial ecology in corporations	- to explain the phases and tools applied in the corporate industrial ecology - to implement environmental management systems in corporations - to implement a policy of pollution prevention in the corporation	- define the phases for implementation the principles of industrial ecology for a given company - select the tools for meeting regulatory requirements for environmental pollution prevention - describe the organizational structure of environmental group in the company and explain the given norm
4. Indicators and Metrics	- to define indicators and metrics - to select indicators and metrics for different spatial scales and organizational entities	- explain the importance and development of indicators and metrics - explain the most common metrics in corporations, and select indicators and metrics for a given company

FORM 2

1) Course teacher: Prof. Sanja Papić, PhD	
2) Name of the course: Surfactants	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: regular	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Explain the basic terms and properties of surfactants 2. List and recognize surfactants from the individual classification groups 3. By mathematical expressions, explain surface phenomena important for the application of surfactants 4. Describe and analyze the processes of production of selected types of surfactants 5. Explain the role of certain compounds in the formulation of detergents	**6) Learning outcomes at the level of the study programme:** 1. Ability to use fundamental knowledge of natural sciences in identifying and describing simple engineering problems 2. Ability to organize and plan simple experiments using the available laboratory equipment and devices 3. Ability to apply the scientific methods in the analysis and modeling of processes and product design

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. The properties of surfactants	-Define the basic terms -Explain the properties of surfactants -Classify surfactants	-Define the basic terms (surface tension, surface active agents or surfactants , micelles, CMC -critical micelle concentration, solubilization) -Relate the specific structure of surfactant molecules with their properties -Know the chemical characteristics, properties and applications of anionic, cationic, nonionic and ampholytic surfactants

FORM 2

2. Surface phenomena important for the application of surfactants	-Explain the phenomena on the surface and at the interface important for the application of surfactants -Apply the mathematical expressions to describe the surface phenomena	-Explain the phase behaviour of surfactants (L/G, L/L, L/S): surface tension, interfacial tension, wetting, stabilization of emulsions and foams using mathematical expressions. -Know the emulsion types. Explain the breakdown and stability of the emulsions. -Explain the foaming, defoaming and stabilising effects in foams.
3. Production processes of selected surfactants	-Describe the processes for the production of selected surfactants -Analyze the process of production of the selected type of surfactant by applying scientific methods	-Describe the processes of preparation of selected anionic, cationic, nonionic and ampholytic surfactants -Know on the basis of the conducted experiment to analyze the process of production of the selected type of surfactant (to evaluate the influence of process parameters)
4. Detergents	-Describe the detergent ingredients -Explain the role of certain compounds in the washing process	-Know the categorization groups of detergents ingredients -Know the role of certain compounds in the washing process -Give example of formulations of detergents for different uses

FORM 2

1) Course teacher: Full Prof.Katica Sertić-Bionda, PhD	
2) Name of the course: Petroleum Refining Processes	
3) Study programme (undergraduate, graduate): undergraduate	
4) Status of the course: elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to identify the main parameters of separation and conversion petroleum refining processes. 2. to relate the composition and characteristics of petroleum/ petroleum products. 3. to recognize the influence of petroleum refining processes parameters on products characteristics. 4. to outline the simple scheme of petroleum refining processes.	**6) Learning outcomes at the level of the study programme:** 1. to apply fundamentals of natural sciences, necessary for identification and description of simple engineering problems. 2. to identify, define and solve simple engineering problems with relevant methodologies and available program packages.

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

Teaching unit	Learning outcomes	Evaluation criteria
1.Separation and conversion processes in petroleum refining	- to identify the main parameters of petroleum refining processes.	- to identify the main parameters of given petroleum refining process (feedstocks, catalysts, prosess variables).
2. Petroleum products	- to recognize the effects of process parameters on products characteristics.	- for given petroleum refining process explain the effects of the main process parameters on characteristics of products.
…..		

FORM 2

1) Course teacher: Prof. dr. sc. Veljko Filipan	
2) Name of the course: ENGINEERING THERMODYNAMICS	
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. apply basic thermodynamics laws for thermodynamic calculations of processes with ideal and real working media 2. apply graphical representation in defining and analysis of thermodynamic processes 3. use tables and diagrams with thermodynamic properties of some particular real working media applied in real processes and devices 4. define energy indicators of thermodynamic processes and devices working in heating and cooling modes	**6) Learning outcomes at the level of the study programme:** 1. apply fundamental principles for identification and description of simple engineering problems 2. define and solve simple engineering problems with relevant methodologies and available program packages 3. chose and apply appropriate mathematical/numerical methods for problem solving 4. apply basic information and communication technologies 5. learning skills and competences required for further vocational training

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

Teaching unit	Learning outcomes	Evaluation criteria
1. basic thermodynamic laws and thermodynamic quantities	- understand basic terms and definitions in engineering thermodynamics - differentiate thermodynamic quantities such as enthalpy entropy, heat, energy and work - connect the 1st and the 2nd law of thermodynamic - differentiate thermodynamic processes according to the direction of the process	- define basic thermodynamic state quantities and thermal quantities - explain analytical expressions of thermodynamic laws - calculate mechanical work due to volume changes and technical work - define basic cyclic processes

FORM 2

2. processes with ideal working media	- define basic processes with ideal gasses; represent them in diagrams - define processes of compression and expansion; differentiate real and ideal ones - calculate reversible and irreversible thermodynamic processes with ideal gas - know achievable cyclic processes	- reproduce and explain the equation of state for ideal and real working media - sketch p,v T,s and h,s diagrams of basic processes with ideal gasses - generate diagrams of achievable cyclic processes - calculate thermodynamic properties and energy performance of particular cyclic processes
3. processes with real working media	- explain thermal properties and changes in real working media - use charts and tables with properties of real working media in calculation of basic process	- sketch and explain diagrams of basic thermodynamic processes with real working media - use h,d diagram for defining real processes with wet air

FORM 2

1) Course teacher: prof. Aleksandra Sander, PhD

2) Name of the course: Chemical engineering laboratory

3) Study programme (undergraduate, graduate): Chemical engineering (graduate)

4) Status of the course: required

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

1. The ability to understand and apply methodologies for solving problems in chemical engineering.
2. The ability to derive mass and heat balances for different types of chemical engineering problems.
3. The ability to mathematically interpret balance equations.
4. The ability to apply appropriate mathematical modeling method for solving chemical engineering problems.

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

1.The ability to recognize importance and the role of chemical engineering as scientific and engineering discipline.

2. The ability to apply methodology for browsing the scientific literature.

3. The ability to work both independently and in multidisciplinary teams as well as to make decisions in complex situations.

4. The ability to develop basic skills for planning and solving complex problems.

5. The ability to enhance graphical and numerical methods for problem solving.

6. The skill to identify, define, solve and present research results related to their problem (orally and in writing).

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Defining problem and its scope, browsing the scientific literature, gaining theoretical knowledge, defining mathematical model of the process, working plan.	- to precisely identify and define chemical engineering problem - to apply methodology for browsing the scientific literature - to relate theoretical and practical aspects of the problem - to plan and work in small	- Oral report – in front of teachers and students

	teams	
2. Establishment of analytical methods and techniques, set-up of the apparatus, defining computer support, plan of the experiment, selection of the optimization methods.	- to plan the experimental set-up - to use the techniques, skills and modern engineering tools necessary for construction of the apparatus - to adopt and apply specific knowledge necessary for the selected analytical methods and techniques	- Oral report – in front of teachers and students
3. Conducting the experiments, development of mathematical model, evaluation of parameters and process optimization	- to adopt and apply advanced specific knowledge necessary for the selected analytical methods and techniques - to acquire skills of mathematical modeling and process optimization	- Oral report – in front of teachers and students
4. Conducting the experiments, validation of the selected mathematical models, and preparation of written final report.	- to apply advanced skills of mathematical modeling and process optimization - to develop the ability for critical evaluation of results - to present research results orally and in writing	- Oral report – in front of teachers and students - written final report

FORM 2

1) Course teacher: Vesna Tomašić	
2) Name of the course: Chemical reactors	
3) Study programme (undergraduate, graduate): Chemical Engineering (graduate)	
4) Status of the course: mandatory	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. define process variables and parameters of chemical reactors 2. develop mathematical models of processes in various types of chemical reactor 3. distinguish different approaches to the modeling of the reactor with respect to the way their work 4. choose the most appropriate reactor with respect to the features of the reaction system, features of process, reaction rate and working conditions 5. describe flow pattern inside the reactor 6. explain the different types of the multiphase reactors 7. apply the appropriate numerical and/or analytical methods to estimate parameters of kinetic models and reactor models.	**6) Learning outcomes at the level of the study programme:** 1. the ability to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods 2. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, social, ethical, health and safety, manufacturability and sustainability 3. 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 4. the ability to identify, define and solve complex engineering problems with relevant methodologies and available program packages.

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

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Kinetics of heterogenous catalytic reactions	- analyze connection between the adsorption phenomena and chemical reaction on the surface of catalyst - define the concept of reaction times and space times - explain the basic features of the Hougen-Watson mechanistic kinetic models - derive kinetic model for the catalyst deactivation with respect to the different mechanisms of deactivation - define the overall effectiveness factor with respect to the interphase and intraparticle diffusion	- explain the approach in developing mechanistic kinetic model - develop a general mechanism of reaction on the example of bimolecular reactions at different active centers - determine from mechanisms the kinetic rate expression and its temperature and concentration dependence - identify the stages in the general reaction pathway for heterogeneous catalytic reaction - describe the difference between physical adsorption and chemisorption - compare the experimental methods to assess the impact of intermediate and intraparticle diffusion on the reaction - demonstrate the ability to use the general reaction engineering principles in different application areas
2. Selection and design of reactors, comparison of basic types of reactors	- define the factors influencing the choice of the reactor - consider the basic types of reactors with respect to their volume - classification of the reaction system with respect to the thermal effects of the reaction - express the temperature sensitivity of reaction	- propose the reactor design on the example of the complex parallel reactions - give examples of possible reactor types for carrying out exothermic reactions - derive an expression for calculating the temperature sensitivity of reaction - assess the potential hazards of various reactor types in case of exothermic reactions - the ability to understand and apply the fundamentals of mathematics, the basic sciences, engineering

		sciences and engineering design methods: - demonstrated in homework, and periodic exams.
3. Batch reactor	- develop the batch reactor model - define the overall heat transfer coefficient with the assumption of the heat exchanged through the reactor walls - explain the optimization of the batch reactor	- write an heat balance equation for the stirred-tank reactor with the heat exchange through the reactor mantle - write an heat balance equation for the reactor in the isothermal work conditions - write an heat balance equation for the reactor in adiabatic work
4. Continuous flow stirred tank reactors (CSTR)	- explain the difference between the continuous flow stirred tank reactors at the stationary and non-stationary conditions (CSTR vs. CSTRn) - derive the reactor model of CSTR - analyze the stability of CSTRs	- write basic mass and heat balance equations for CSTR and CSTRn - simplify the basic mass and heat balance equations with the use of equivalent units or with the assumptions of the specific reaction conditions - write heat balance equations of CSTR for different types of heat exchange
5. Tubular reactors	- summarize the basic features of the tubular reactors - explain the complexity of the mathematical models of the tubular reactors - explain models of flow in CR - illustrate the essential features of 1D and 2D models for homogeneous and heterogeneous systems - calculation of the appropriate mass and heat transfer coefficients	- identify factors that affect the complexity of the mathematical models of tubular reactors - explain the model of axial dispersion - write a model of the tubular reactor with laminar flow - compare the methods for solving equations of the reactor models - apply appropriate numerical method for solving model equations

FORM 2

6. Multiphase reactors	- summarize the basic features of multiphase reactors - analyze the performance of the gas-liquid reactors - describe the performance of three-phase reactor with a catalyst as solid phase - explain the classification of the multi-phase reactors	- give examples of major design types of the multiphase reactors - generate examples of reactions in two-phase and three-phase systems - summarize the general features of the multiphase reactors - design and interpret rate experiments, assess the effect of transport phenomena on observed rates and determine the rate of reaction - quantify the effect of operating variables in various reactor types on product quality and purity and energy efficiency

FORM 2

<table>
<tr><td colspan="2">1) Course teacher: Full Prof. Katica Sertić-Bionda, PhD., Full Prof. Ante Jukić, PhD.</td></tr>
<tr><td colspan="2">2) Name of the course: Petroleum Refining and Petrochemical Processes</td></tr>
<tr><td colspan="2">3) Study programme (undergraduate, graduate): graduate</td></tr>
<tr><td colspan="2">4) Status of the course: compulsory</td></tr>
<tr><td>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 recognize the effects of petroleum refining and petrochemical process parameters on yields and composition of products.
3. to distinguish the relevance of processes regarding the application and ecological requirements on the products.
4. to estimate the reaction mechanisms for selected examples.
5. to outline the simple scheme of petroleum refining and petrochemical processes.
6. to compare the conventional and developing petroleum refining and petrochemical processes.
…..</td><td>6) Learning outcomes at the level of the study programme:
1. to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods.
2. to identify, define and solve complex engineering problems with relevant methodologies and available program packages.</td></tr>
<tr><td colspan="2">7) Teaching units with the corresponding learning outcomes and evaluation criteria</td></tr>
</table>

Teaching unit	Learning outcomes	Evaluation criteria
1. Separation processes in petroleum refining; distillation, adsorption, extraction. Conversion	- to recognize the effects of petroleum refining process parameters on yields and composition of products.	- for given petroleum refining process explain the effects of process variables, catalysts and type of feedstocks on

FORM 2

processes in petroleum refining; catalytic cracking, hydrocracking, catalytic reforming, isomerization, alkylation, hydrotreating, mineral oils production		yields and properties of products.
2. Petrochemical processes: natural gas treatment, production of syngas (hydrogen), synfuels by Fischer-Tropsch synthesis, ammonia and theri main derivatives.	- to identify and understand reaction mechanism of the main petrochemical processes. - to outline the simple schemes of of the main petrochemical processes.	- for a given petrochemical process explain the effects of process variables, catalysts and type of feedstocks on yields and properties of products.

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FORM 2

1) Course teacher: Vesna Tomašić

2) Name of the course: Catalytic reaction engineering

3) Study programme (undergraduate, graduate): Chemical Engineering (graduate)

4) Status of the course: mandatory

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

1. explain an integrated approach to design of catalysts and reactors
2. distinguish between different types of catalytic reactors
3. choose the appropriate type of reactor with respect to the features of the reaction system, the features of the process, the reaction rate and working conditions
4. classification of the catalytic reactors with respect to the given features (number of the phases, the movement of the catalyst inside the reactor, temperature distribution inside the reactor, the heat exchange)
5. summarize the general problems connected with the performances of the fixed bed reactors
6. apply the appropriate numerical and/or analytical methods to estimate parameters of kinetic models and reactor models.

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

1. the ability to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods
2. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, social, ethical, health and safety, manufacturability and sustainability
3. 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
4. the ability to identify, define and solve complex engineering problems with relevant methodologies and available program packages.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Introduction to kinetics and mechanism of the reaction, determination of the reaction regime; integrated approach to	- explain the meaning of the term catalytic reaction engineering - describe historical development and economic	- explain the field of application of the results of kinetic studies in the industry - explain what makes the chemical reactors differ from

design of catalysts and reactors	importance of catalysis and its role in the development of chemical industry - identify the basic features of catalysis in the context of the development of sustainable technologies - outline the influence of different factors on the choice and design of catalytic processes for a particular purpose	the other processing units - describe the difference between the differential and integral reactor
2. Experimental methods of testing in the laboratory reactors	- analyze experimental methods of the catalysts at the laboratory conditions - explain the way of collecting, analyzing and processing the data obtained in laboratory reactors	- discuss the principle of work of gradientless reactors - summarize criteria for the selection of laboratory experimental reactor
3. Classification of the catalytic reactors	- summarize the basic features of the catalytic reactors - explain the classification of the catalytic reactors with respect to the number of phases and the nature of catalysis - assess different possibilities to remove the heat developed/released reaction - - identify factors that influence the choice and performance of the catalytic reactor - explain methods for the separation of catalyst and reaction products on the example of the homogeneous catalytic reactions	- summarize the factors that affect the performance and calculation of catalytic reactors - describe critical aspects of performing the reaction in the gas and liquid phase - give examples of multi-phase reaction

FORM 2

4. Special features of the fixed bed reactor	- analyze the performance of the fixed bed catalytic reactors - analyze the working principle of the adiabatic reactor; define the conditions for adiabatic operation of the reactor - explain the problems in the design of the fixed bed reactors - analyze the flow pattern through a fixed bed reactor - define the terms of the axial and radial dispersion - summarize the general features of the commercial fixed bed reactors	- recognize the advantages and disadvantages of the fixed-bed reactor in comparison to the other types of catalytic reactors - explain deviations from the ideal flow conditions and explain the reasons - express the criteria that determine the maximum allowed pressure drop in the reactor - determine the pressure drop through the catalytic layer using the appropriate empirical correlations
5. Moving bed reactors	- summarize the basic features of the moving bed reactors - classification of the moving bed reactors - describe advantages and disadvantages of the moving-bed reactors - explain the basic principles of work of the fluidized bed reactors - analyze the heat and mass transfer processes in the suspension reactors	- give examples of different designs of the moving bed reactors and specify the area of their application - interpret the advantages of the moving bed reactors in relation to the other types of multiphase reactors - analyze the pressure drop in the moving bed reactors - explain the experimental method used for determination of the fluidization points - compare the performance of the trickle bed and suspension reactors

FORM 2

1) Course teacher: Vesna Tomašić
2) Name of the course: Air Pollution Control Equipment
3) Study programme (undergraduate, graduate): Chemical Engineering (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. describe fundamental concepts in air protection 2. classify sources of air pollution 3. evaluate air quality management and analyze the causes and effects of air pollution 4. recognize major legislation governing air pollution 5. explain the mechanisms of pollutants formation 6. classify various air pollution control methods and the costs to implement those controls 7. analyze a methodology to determine the performance of air pollution control techniques 8. describe design of control technologies 9. apply the appropriate numerical and/or analytical methods for solving practical environmetal problems 10. recommend control strategies for specific air polution problems	1. the ability to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods 2. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, social, ethical, health and safety, manufacturability and sustainability 3. 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 4. the ability to identify, define and solve complex engineering problems with relevant methodologies and available program packages

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
Sources of air pollution, defining basic terms, classifications	- analyze the composition and structure of the atmosphere - define basic concepts (pollution, pollutant, contaminant, emission, aerosols, etc.). - explain the greenhouse effect	- explain the consequences of the air pollution - describe the impact of pollution on human health - recognize the effects of global air pollution - explain the basic principles of

FORM 2

	- explain the history of air pollution - analyze classification of pollutants according to their physical state - describe the mechanisms of pollutants formation and formation of gaseous pollutants (gases and vapors)	the air pollution monitoring - identify current research questions in the field of air quality engineering
Approach to solving problems in air protection	- explain the different approaches of solving problems in air protection - compare the primary and secondary processes used to protect the air - analyze the industrial plants with regard to sources of pollution	- classify end-of-pipe processes in the air protection - give examples of application of the process-integrated approach to the environmental protection - give a schematic representation of an industrial plant with an indication of possible sources of emissions into the environment - discuss the basic types of emissions from industrial plants
Removal of particulates from waste gases	- classify methods for removing particulates from the stationary sources - consider the advantages and disadvantages of mechanical and physical methods of separation - explain the factors that influence the selection of the appropriate process - define the characteristic dimensions that describe the motion of the solid particles in the fluids - describe particulate control equipments - explain the wet process for particulates removal	- compare wet and dry processes for particulates removal - describe operation of dry process - give examples of different designs of devices based on wet processes - explain the influence of process parameters on the removal of the suspended particles - calculate the efficiency of cyclone - summarize the effectiveness of different systems for dust removal with respect to the particle size

FORM 2

Removal of gaseous pollutants (gases and vapors)	- consider the similarities and differences between the gases and vapors - compare absorption vs. adsorption - explain the different performance absorber - analyze the working principle of the adsorber - describe condensation and membrane separation processes and chemical procedures for the treatment of waste gases - explain the basic principles of the biological treatment of waste gases	- comparable scrubbing and stripping - specify the application of the absorption process in the air protection - indicate the parameters that affect the efficiency of the adsorber - compare different types of condensers - consider differences between thermal and catalytic processes - compare recuperative and regenerative combustion devices
Treatment of exhaust gases from the mobile sources	- classify methods for the treatment of exhaust gases from mobile sources - explain the working principle of the three way catalysts - specify the basic features of monolithic catalysts and catalytic converters - describe treatment of exhaust gases from diesel engines suspension reactors	- explain the role of monolithic structures in the field of the air protection

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FORM 2

1) Course teachers: Associate. prof. Ana lončarić Božić, PhD **Assistant prof. Hrvoje Kušić, PhD**
2) Name of the course: Environmental engineering
3) Study programme: 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. Understand and adopt the concept of sustainable development and the role of chemical engineers in environmental protection 2. Adopt the basic principles and tools for preventive approach in environmental protection 3. Correlate the sources of environmental pollution with the corresponding mitigation and minimisation measures 4.Understand, adopt and apply the basic principles of green chemistry and green engineering in the process and product development 5. Quantify the environmental impact of different chemical processes 6. Understand the role of catalysis in development and application of sustainable processes and products 7. Be acquainted with the key requirements of national Environmental protection law and IPPC directive 8. Correlate sources of air, soil and water pollution and transportation paths in environment 9. Be acquainted with management tools in environmental engineering	1. Apply the fundamental knowledge in chemical engineering in identifying and solving the environmental problems 2. Understand the role of chemical engineering in proactive approach within the field of environmental engineering 3. Acquire knowledge and competences required for further professional development within the field of environmental engineering

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Introduction to Environmental engineering; sustainable development and	-adopt the main terms in environmental engineering and be acquainted with the	- explain the main terms in the field of environmental protection and environmental

preventive approach in environmental protection	key requirements of national Environmental protection law - understand the concept of sustainable development and the role of chemical engineers in environmental protection - adopt the basic principles and tools for preventive approach in environmental protection - understand the sources of environmental pollution and correlate them with the corresponding mitigation and minimisation measures	engineering - identify the sources and transportation paths of pollutants in studied environmental systems - apply the conservation laws for monitoring the pollutants in environment -explain the waste management hierarchy through the methodology of cleaner production - correlate the sources of waste/pollution generation in chemical processes with the corresponding preventive measures based on given examples
2. Role of green chemistry and green engineering in sustainable development	- define terms “green chemistry” and “green engineering” -understand and apply adopt basic principles of “green chemistry” and “green engineering “ in process and product development -quantify the environmental impacts by application of atom economy and calculation of E-factor - apply the „green indicator” in life cycle analysis of products. - understand the importance of catalysis in development of sustainable processes	-apply the principles of green chemistry and green engineering in process and product development based on given examples - calculate E-factors and atom economy in order to quantify environmental impacts of given processes - select less harmful raw materials and solvents in process development – explain the role of catalyst in design of alternative reaction path considering savings in materials, energy and minimisation of environmental impact
3. Analysis and control of environmental pollution	- understand the main sources and transportation paths of air, soil and water pollution - be acquainted with management tools in environmental engineering u - be acquainted with the main features of IPPC directive	- identify the correlation between the particular anthropogenic activities and the presence of specific pollutants in environment - overview the main features of environmental management systems (EMS and EMAS) and

	management tools in environmental engineering poznavati glavne značajke IPPC direktive - select and propose appropriate measures for minimization and control of environmental pollution	environmental impact assessment (EIA and SEA) - explain the term „Best available technologies“ and their role in IPPC directive - specify and describe the main sources and mechanisms of ozone depletion - propose the appropriate water treatment method based on given water characteristics - explain the processes of soil remediation and based on given examples

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FORM 2

1) Course teacher: Helena Otmačić Ćurković	
2) Name of the course: Structural materials – corrosion and protection	
3) Study programme (undergraduate, graduate): graduate	
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 various structural materials 4. discus new trends in development of structural materials 5. explain the principles of different corrosion protection techniques 6. estimate which corrosion protection technique is the most appropriate for a given corrosion issue	**6) Learning outcomes at the level of the study programme:** 1. the ability to understand and apply the fundamentals of the basic sciences, engineering sciences and engineering design methods 2. the ability to identify, define and solve complex engineering problems with relevant methodologies and available program packages; 3. the ability to use the techniques, skills and modern engineering tools necessary for engineering practice;

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 corrosion occurrence in dependence of given	- draw corrosion cell - determine possibility of corrosion reaction by using Pourbaix diagram -discriminate anodic polarization curves of passivating and non passivating metals

	thermodynamic parameters -explain metal passivity	- 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 metallic coatings -explain how each corrosion	- 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

	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 structural materials - explain how they can be determined	- explain given physical property and how it can be measured
6. Important structural materials	- describe the most important chemical and physical properties, as well as the common application areas of the most important metallic, inorganic and organic structural materials	- describe the most important chemical and physical properties, as well as the common application areas of given structural material
7. New structural materials	-explain the basic principles of composite, smart and biomimetic materials -discus the key issues related to the use of nanomaterials	-explain the basic principles of composite, smart and biomimetic materials -explain advantages and disadvantages of nanomaterials

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FORM 2

1) Course teacher: Prof. Sanja Papić, PhD	
2) Name of the course: Technological processes of organic industry	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: regular	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Describe the features and recognize the role of the organic chemical industry. List important products and state their application. 2. Classify the processes of the organic chemical industry. For each basic process (sulfonation, nitration, amination by reduction, oxidation, alkylation, hydrolysis, halogenation) select the reaction agents, explain the influence of process parameters and reaction mechanisms. Apply knowledge of reaction engineering and technical thermodynamics and explain the process kinetics and thermodynamics. 3. Describe the industrial processes for the production of selected, important intermediates of organic chemical industry. Explain the flow diagrams. 4. Create a flow diagram for the production of a given intermediate. 5. Give an example of process improvement in terms of better selectivity and environmental acceptability. Judge, evaluate and argue the environmental acceptability of processes of organic chemical industry.	**6) Learning outcomes at the level of the study programme:** 1. Ability to apply basic knowledge of the natural sciences in identifying and describing simple engineering problems. 2. Ability to apply scientific methods in the analysis and modelling of processes and product design. 3. Ability to understand the importance and the role of engineers in society and the necessity for the highest ethical standards in their professional work. 4. Ability to identify, define and solve simple engineering problems by applying the appropriate methodology and available software packages.

FORM 2

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Features and role of the organic chemical industry	-describe the features and recognize the role of the organic chemical industry -list the important products and state their application.	-explain the features and the role of the organic chemical industry in a modern economy -to know the important products and their application. -list the basic processes
2.Basic processes of organic chemical industry	-classify the processes of the organic chemical industry -for each basic process (sulfonation, nitration, amination by reduction, oxidation, alkylation, hydrolysis, halogenation) select the reaction agents, explain the influence of process parameters and reaction mechanisms -apply knowledge of reaction engineering and technical thermodynamics and explain the process kinetics and thermodynamics	For each basic process to know: - reaction agents -mechanisms and kinetics of chemical reactions - thermodynamic features - explain the influence of process parameters -important products and their application
3)Selected industrial processes for the production of important intermediates of organic chemical industry	-describe the industrial processes for the production of selected, important intermediates of organic chemical industry -explain the flow diagrams	- describe the industrial processes for the production of selected intermediates - explain the process flow diagrams

	-create a flow diagram for the production of a given intermediate	- know the application of certain intermediates in the production of important products of organic chemical industry
4) Examples of environmentally friendly processes	-give an example of process improvement in terms of better selectivity and environmental acceptability -judge and evaluate the environmental acceptability of processes of organic chemical industry	-to give an example of improving the process of organic chemical industry to achieve better selectivity and environmental acceptability

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FORM 2

1) Course teacher: Assoc. Prof. Elvira Vidović, PhD	
2) Name of the course: Petrochemical Technology	
3) Study programme (undergraduate, graduate): graduate	
4) Status of the course: required	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. to distinguish the procedure of conversion of fossil and renewable raw materials into a spectrum of chemicals and materials 2. to relate the previous knowledge (organic, physical chemistry) and others (thermodynamics, transfer phenomena) with the processes of petrochemical industry 3. to differentiate the technological solutions characteristic for petrochemical industry 4. to outline the schemes of main processes in petrochemical industry.	**6) Learning outcomes at the level of the study programme:** 1. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, social, ethical, health and safety, manufacturability and sustainability 2. the ability to understand social importance and the role of engineering as well as the importance of the highest ethical standards in professional work

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Natural gas – composition and exploitation; treatment processes	- to define natural gas regarding the composition and physico-chemical properties	- to identify natural gas regarding the composition and physico-chemical properties
2. Processes of production and processing of aromatic hydrocarbons	- to analyze the technological processes of separation of aromatic hydrocarbons (BTX) mixtures into single components	- to discriminate the starting point of processes of separation of aromatic hydrocarbons

FORM 2

1) Course teacher:

Prof. Sanja Lučić Blagojević, Ph.D.

2) Name of the course:

Polymer nanocomposiues

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 teacher: Prof. Irena Škorić, Ph.D. Prof. Vesna Volovšek, Ph.D.	
2) Name of the course: Molecular spectroscopy	
3) Study programme (undergraduate, graduate): Chemical Engineering (graduate)	
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	-to recognize and interpret spectra of simple molecules; -to determine the structure of the compound on the basis of

	IR and UV/VIS spectra; - 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

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FORM 2

1) Course teachers: Associate. prof. Ana Lončarić Božić PhD	
2) Name of the course: Environmental management systems	
3) Study programme: graduate KI	
4) Status of the course: elective	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. the ability to apply the methodology of Environmental management systems based on Deming's cycle of continual improvement 2. the ability to analyse processes, activities and corresponding environmental aspects and impacts 3.the ability to propose preventive measure for potential environmental problems related to different processes and activities 4. the ability to recognise and response to the specific environmental issues related to inherent risks of chemical industry	**6) Learning outcomes at the level of the study programme:** 1. the ability to apply basics of professional protection of local and global environment, environmental development and control, and environmental legislation ; 2. the ability to perform critical analysis of environmental problems. 3. the ability to understand and solve environmental issues using environmental management tools

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Basic principles of sustainable development; Introduction to Environmental management system (EMS) based on Demig's cycle; ISO 14001	- adopt the preventive approach in environmental protection and management -understand the role of Demings' cycle in continual improvement - understand the significance of the main elements and their correlation within EMS - understand the requirements of ISO 14001 -analyse processes, activities and corresponding environmental aspects and impacts	- describe and explain the basic principles of preventive approach and EMS as a sustainable development tool -specify the elements of Demings' cycle and describe the concept of continual improvement - explain the requirements for environmental policy according to ISO 14001 -set "smart "EMS objectives based on given examples -define environmental aspects and impacts based on activities described in given

FORM 2

		case study - distinguish types of EMS documentation
2. Cleaner production, Life Cycle Analysis (LCA) and Responsible care	- understand and adopt the methodology of Cleaner production, Life Cycle Analysis (LCA) and Responsible care - correlate sources of waste in Cleaner production with corresponsive preventive measures - understand the importance and main characteristics of programme Responsible care in chemical industry	-describe and explain the basic elements of Cleaner production, Life Cycle Analysis (LCA) and Responsible care methodology -classify types of waste sources in Cleaner production -specify and explain applicability of preventive measures in Cleaner production -describe inherent environmental and health risks in chemical industry -explain principles of Responsible care their correlation with the EMS methodology

FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD
2) Name of the course: Degradation and Modification of Polymers
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. to understand and analyze the basic knowledge related to the processes of degradation of polymeric materials 2. acquisition of the ability to understand mechanism of different types of polymer degradation: mechanical, photooxidative degradation, thermal degradation, biodegradation… 3. acquisition of the ability to understand the methods and processes of polymer modification, chemical and physical 4. ability of self presentation and interpretation of laboratory results in written and oral form	1. application of scientific principles, which include basic principles of chemistry and chemical engineering, on materials, their structure and properties 2. the ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering; 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. Introduction to degradation processes, mechanisms of degradation	- acquisition of knowledge about degradation processes, to indicate the type of degradation: mechanical, photooxidative degradation, thermal degradation, biodegradation… - to define the mechanism of different degradation reactions	-to explain the basic principle of polymer degradation processes -to distinguish different types of polymer degradation reactions
2. Thermal and	- understanding of	-to recognize the effect of – -

photooxidation, oxygen and ozone activity, mechanical degradation.	temperature and oxygen effect on polymer materials; depolymerization reactions and their influence to polymer chain structure and molecular weight of polymers - to explain the effect of mechanical stresses on the properties of polymer materials	- to explain the influence of thermal and mechanical degradation and photodegradation on the properties of polymer materials -to define the various structure changes in polymer materials caused by degradation processes
3. Degradation of biopolymers -biodegradation.	- to explain the term biopolymers and biodegradation. - to indicate the effect of biodegradation on the polymer materials properties.	- to define and explain different types of biopolymers and biodegradable polymers -to define the products of polymers biodegradation.
4. Modifications of polymers, Multifunctional systems - compatibility.	- to indicate the basic types of polymer modifications: polymer blends, polymer composites - to define the polymer materials compatibility	-to define the types of polymer modifications -to explain the basic principles of polymer materials compatibility, polymer blends, polymer composites
5. Thermodynamics of multifunctional polymer systems	- to acquire the knowledge about thermodynamics of multifunctional polymer systems	-to define the basic equations for thermodynamics in polymer multifunctional systems
6. Chemical and physical modifications of polymers.	- acquisition of knowledge about the basic methods for chemical modifications of polymers: graft polymerization, copolymerization; physical modifications of polymers: homogenization in the melt and in the solution	-to define the basic methods for chemical and physical modifications of polymers - to explain the influence of polymer modification on the materials properties

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FORM 2

1) Course teacher: Prof. Zlata Hrnjak-Murgić, PhD
2) Name of the course: Cellulose and Paper 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):	**6) Learning outcomes at the level of the study programme:**
1. acquisition of knowledge related to manufacturing cellulose from wood 2. understanding and basic knowledge regarding the manufacturing of paper 3. adoption of knowledge of various technology and equipment for paper manufacturing 4. adoption of knowledge of production of cardboard and corrugated cardboard 5. acquisition of knowledge for the analysis of quality control and production	1. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, health and safety, manufacturability and sustainability 2. the ability to understand and apply specific chemical engineering skills such as mass and energy balances, heat and mass transfer operations, process economics, process design, process safety and process design 3. understanding of engineering processes and their design 4. recognition and finding solutions to problems regarding environmental protection

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Manufacturing cellulose from wood	- to define type of wood and wood fibres -to identify chemistry of wood; cellulose, hemicellulose, lignin -to acquire the knowledge about the methods for quality control	-to explain technology of cellulose separation from wood - to distinguish the main components of wood and their chemistry -to distinguish the methods for quality control
2. Manufacturing cellulose from wood	-to define technology of wood pulp -to define technology of semi	-to explain and understand technology of wood pulp production

	cellulose - neutral sulphite process, cold alkali process.	-to explain and understand technology of semi cellulose
3. Manufacturing cellulose from wood	-to define technology of sulphite pulp-acid process. -to define technology of sulphate pulp-alkali process	-to explain and understand technology of sulphite pulp-acid process -to explain and understand technology of sulphate pulp-alkali process
4. Regeneration of chemicals	- to indicate the regeneration of chemicals from white and black liquor - to define the significance and negative impact on environment	-to distinguish processes for chemical recovery from the process mixture - to explain the negative impact on environment
5. Manufacturing of paper	-to define technology of paper production, preparation of mixture: fillers, binders, colours - to define preparation of paper pulp - to indicate paper – machine production - to define technology of cardboard and corrugated cardboard preparation	-to distinguish processes for paper production -to explain paper pulp and machinery for production -to distinguish processes for cardboard preparation
6. Quality control of processes and product	-to define the methods for analysis control and monitoring process of the paper production	-to distinguish necessary methods for monitoring the production and quality

FORM 2

1) Course teacher: Prof. Bruno Zelić, PhD	
2) Name of the course: Bioseparation Processes	
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 apply basic principles of mass and energy conservation on physical, chemical and biochemical processes 2. to define process space, system borders, and inlet and outlet process parameters 3. to differentiate steady-state and non steady-state, closed and open process 4. to develop mass and energy balances of case studies 5. to construct process schemes of biochemical industrial processes 6. to differentiate between bioseparation processes needed for separation, isolation and purification of biochemicals	**6) Learning outcomes at the level of the study programme:** 1. to apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods; 2. to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, social, ethical, health and safety, manufacturability and sustainability; 3. to 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; 4. to apply and optimize chemical and related industrial processes 5. to identify, define and solve complex engineering problems with relevant methodologies and available program packages; 6. to chose and apply appropriate - mathematical/numerical methods for problem solving; 7. to use the techniques, skills and modern engineering tools necessary for engineering practice

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

Teaching unit	Learning outcomes	Evaluation criteria

FORM 2

1. Bioseparation processes	- to apply basic principles of mass and energy conservation on physical, chemical and biochemical processes - to define process space, system borders, and inlet and outlet process parameters - to differentiate steady-state and non steady-state, closed and open process - to develop mass and energy balances of case studies - to construct process schemes of biochemical industrial processes	- construct process scheme for case study and identify inlet and outlet process streams and parameters - determine the base for calculation and standard conditions - seek literature data needed for calculation of mass and energy balances - apply the principle of mass and energy conservation and develop mass and energy balances for case study
2. Process integration	- to differentiate between bioseparation processes needed for separation, isolation and purification of biochemicals	- develop integrated bioseparation process for separation, isolation, and purification of target biochemical

FORM 2

1) Course teacher: Mandić Zoran, PhD, associate professor

2) Name of the course: Electrochemical energy conversion and storage devices

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:**
- Educate students in the construction, chemistry, thermodynamics and properties of electrochemical energy conversion and storage devices (ECSD) - Provide an experience that encourages development of independent thought and engineering approach to the design and application of ECSD - Enable sufficient skills for the testing and installation of ECSD in different energy systems and technology - Understand the working principles of batteries, fuel cells and supercapacitors	- Students will be able to recognize the importance of electrochemical energy storage devices in solving energy challenges and providing sustainable development - Students must be able to identify and test the properties of electrochemical energy storage devices. - Students will acquire necessary knowledge for design and construction novel electrochemical energy storage devices. - Students will be able to select appropriate electrochemical energy storage devices meeting specific practical requirements and limitations.

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. chemistry and thermodynamics of electrochemical energy storage devices	- understand the principles of electrochemical energy storage devices - recognize the importance of electrochemical energy storage devices in energy systems and technology - calculate electromotive force from the thermodynamic data	- explain basic operation mechanisms of electrochemical energy storage devices - apply knowledge in calculation of electrical, electrochemical and thermodynamic parameters of electrochemical energy storage devices -

FORM 2

2. Design and testing of electrochemical energy storage devices	-explain the prerequisites for the construction of efficient electrochemical energy storage devices - describe the operation of batteries and fuel cells and their differences - understand the role of supercapacitors - apply different methods in testing of electrochemical energy storage devices	- sketch charging/discharging mechanisms of electrochemical energy storage devices - construct active electrodes for electrochemical energy storage devices - apply electrical methodology in the evaluation of electrochemical energy storage devices

FORM 2

1) Course teacher: Full Prof.Katica Sertić-Bionda, PhD.

2) Name of the course: Petroleum Fuels and Lubricants

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 identify the main process parameters and their influence on products (fuels, lubricants) characteristics.
2. to classify the processes of fuels and lubricants production and treatment.
3. to define the physical and chemical properties and specifications of fuels and lubricants.
4. to relate the physical and chemical properties of fuels and lubricants with applied additives.
5. to analyse the influences of fuels characteristics on vehicle exhaust emissions.

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

1. to understand and apply the fundamentals of mathematics, the basic sciences, engineering sciences and engineering design methods.
2. to identify, define and solve complex engineering problems with relevant methodologies and available program packages.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Petroleum fuels	- to relate the physical and chemical properties of fuels with applied additives.	- to identify the types of additives for given fuel to improve its physical and chemical properties.
2. Petroleum lubricants	- to classify the processes of lubricants production and treatment.	- to classify the processes of given lubricant production and treatment.

FORM 2

1) Course teacher: Helena Otmačić Ćurković

2) Name of the course: Corrosion and environment

3) Study programme (undergraduate, graduate):graduate

4) Status of the course:

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

1. identify hazards that corrosion and inadequate corrosion protection present to environment and human health;
2. identify how some of the corrosion protection methods may endanger environment and human health due to the release of toxic compounds;
3. estimate which corrosion protection method is the most adequate for given corrosion issue;
4. relate presence of pollution and climatic parameters to the corrosion level of various structural materials.

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

1. the ability to understand and apply the fundamentals of the basic sciences, engineering sciences and engineering design methods;
2. the broad education that is necessary to understand the impact of engineering solutions in global, economic, and social contexts;
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. English language fluency;

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Environment pollution	- indentify common sources of pollution -discuss different approaches towards reduction of pollution caused by industry	- student should indentify the most common sources of pollution -student should explain the principles of sustainable development
2. Corrosion processes	-explain causes of corrosion -distinguish various types of corrosion processes	- identify causes of corrosion and possible type of corrosion that will occur for specific material in given environment.

FORM 2

		-write corrosion reactions for selected combination metal-environment
3. Harmful substances released to environment due to the corrosion or in corrosion protection	-explain which harmful substances can be released to environment due to the corrosion or in corrosion protection - explain the influence on environment and human health of the most common pollutants related to the corrosion processes	-name harmful compound that can be released from particular construction or process related to corrosion protection and explain its influence on environment and human health
4. Corrosion damage	-analyze the importance of corrosion protection for safe operation of various industrial processes and stability of metallic constructions, - identify the critical parts of metallic constructions or technological processes where inadequate corrosion protection may cause serious damage	-explain the causes of known corrosion failure -experimentally determine the corrosion rate of metallic materials used in medicine as implants.
5. Influence of environment parameters on corrosion type and rate	-correlate changes in environment with corrosion stability of metallic materials - relate presence of pollution and climatic parameters to the corrosion level of various structural materials	- explain key factors that lead to damage of cultural heritage and other constructions in polluted environment - experimentally determine corrosion rate of bronze in different environments
6. Corrosion protection methods	- identify potential hazards of application of various corrosion protection methods -explain which modifications in existing corrosion protection methods are	-explain potential hazards of some corrosion protection method and how they can be overcome

	needed to comply with recent environmental regulation	

FORM 2

1) Course teacher: Assoc. Prof. Gordana Matijašić, PhD	
2) Name of the course: Particulate Systems	
3) Study programme (undergraduate, graduate): Chemical Engineering, Graduate	
4) Status of the course: Optional	
5) Expected learning outcomes at the level of the course (4-10 learning outcomes): 1. Define and categorize particulate systems, their properties, sampling methods and methods of measurement, interpretation and approximation of particle size distribution 2. Define methods for determination of powder rheology. 3. To analyze powder mixing, conveying and storage. 4. To analyze health effects, fire and explosion hazards of fine powders.	**6) Learning outcomes at the level of the study programme:** 1. The ability to apply scientific methods in process analysis and modelling and in product design. 2. The ability to understand basic methods of characterization. 3. To analyze complex chemical engineering problems. 4. The ability to practice chemical engineering methodology in product development. 5. The ability to work both independently and in multidisciplinary teams.

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Properties and behavior of particulate systems	- analyze the properties of powders - recognize the methods of powder sampling and characterization - define rheological parameters and methods of determination powder fluidity	- define powder types - explain methods of powder sampling - list and explain methods of characterization - explain particle shape - distinguish particle and bulk properties - define powder rheology - explain methods for determination of powder

FORM 2

		fluidity - define flow index - sketch the graphical representation of powder flow functions
2. Particulate solids handling	- define mechanisms and kinetics of powder mixing - categorize and explain working principle of powder blenders - explain powder segregation - analyze conveying and storage of powders	- describe and explain mixture quality - explain mixing mechanisms - sketch mixing curve - explain mixing kinetics and determination of mixing rate constant - categorize blenders - explain working principle of powder blenders and possible problems in mixing - explain criteria for blender selection - explain particle segregation, mechanisms of segregation and causes and consequences of segregation - explain pneumatic conveying - calculate examples of pneumatic system scaling - list silos types - calculate examples of silos design
3. Handling hazards and health effects of fine powders	- define dust explosion mechanisms and key values for their definition - analyze positive and negative effect of fine powders on human health	- explain condition that will lead to dust explosion - define terms: spontaneous ignition, ignition temperature, minimum ignition energy, flammability limits - sketch dust fire and explosion pentagon - explain possible positive

		and negative effects of fine powders on human health

FORM 2

1) Course teacher: Helena Otmačić Ćurković

2) Name of the course: Corrosion and environment

3) Study programme (undergraduate, graduate):graduate

4) Status of the course:

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

1. identify hazards that corrosion and inadequate corrosion protection present to environment and human health;
2. identify how some of the corrosion protection methods may endanger environment and human health due to the release of toxic compounds;
3. estimate which corrosion protection method is the most adequate for given corrosion issue;
4. relate presence of pollution and climatic parameters to the corrosion level of various structural materials.

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

1. the ability to understand and apply the fundamentals of the basic sciences, engineering sciences and engineering design methods;
2. the broad education that is necessary to understand the impact of engineering solutions in global, economic, and social contexts;
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. English language fluency;

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Environment pollution	- indentify common sources of pollution -discuss different approaches towards reduction of pollution caused by industry	- student should indentify the most common sources of pollution -student should explain the principles of sustainable development
2. Corrosion processes	-explain causes of corrosion -distinguish various types of corrosion processes	- identify causes of corrosion and possible type of corrosion that will occur for specific material in given environment.

FORM 2

		-write corrosion reactions for selected combination metal-environment
3. Harmful substances released to environment due to the corrosion or in corrosion protection	-explain which harmful substances can be released to environment due to the corrosion or in corrosion protection - explain the influence on environment and human health of the most common pollutants related to the corrosion processes	-name harmful compound that can be released from particular construction or process related to corrosion protection and explain its influence on environment and human health
4. Corrosion damage	-analyze the importance of corrosion protection for safe operation of various industrial processes and stability of metallic constructions, - identify the critical parts of metallic constructions or technological processes where inadequate corrosion protection may cause serious damage	-explain the causes of known corrosion failure -experimentally determine the corrosion rate of metallic materials used in medicine as implants.
5. Influence of environment parameters on corrosion type and rate	-correlate changes in environment with corrosion stability of metallic materials - relate presence of pollution and climatic parameters to the corrosion level of various structural materials	- explain key factors that lead to damage of cultural heritage and other constructions in polluted environment - experimentally determine corrosion rate of bronze in different environments
6. Corrosion protection methods	- identify potential hazards of application of various corrosion protection methods -explain which modifications in existing corrosion protection methods are	-explain potential hazards of some corrosion protection method and how they can be overcome

FORM 2

	needed to comply with recent environmental regulation	

FORM 2

1) Course teacher:

Prof. Sanja Lučić Blagojević, Ph.D.

Prof. Mirela Leskovac, Ph.D.

2) Name of the course: Formulation Engineering

3) Study programme (undergraduate, graduate):

Graduate program Chemical engineering

4) Status of the course: regular

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

1. To apply product engineering principles and methodology in product design and production.
2. To appraise product quality functions with regard to properties, process and application functions.
3. To create new products with functional properties and added value.
4. To demonstrate and sketch diagrams, and practical performance development of the product according to market needs.
5. To design a new product combining multiple functions of engineering and manufacturing, industrial design and marketing.

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

1. To analyze, optimize and connect the fundamental elements of the process and production in the chemical and related industries.
2. To manage and plan the new processes, product design and sustainable production.
3. To identify, define and solve complex problems in the field of chemical engineering.
4. To apply the methods, models and techniques in solving case studies.
5. To apply and deepen the generic knowledge and methodology of chemical engineering in the integral development of the process and product for market by using original ideas.

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Product engineering and design	- to apply the tools and methods of product engineering for the selected product - to apply the design of	- define the concept and explain the methodology of product design - connect functions of quality, properties, processes

	chemical processes and products - to sketch the pyramid of chemical product - to apply the principles of formulating a given product - to apply knowledge of the operations and processes important in the formulation engineering in product design	and applications in the design of the product - assess the quality factors of the selected product - explain the methods of formulating at example of product - outline the scheme to product prototype with new functional properties
2. Surface and interface phenomena and selected processes in formulation engineering	- to optimize the conditions at the interface - to apply the knowledge of the colloidal disperse systems used in the formulation of emulsions, dispersions and suspensions - to use methods of predicting properties	- calculate and predict the conditions of thermodynamic stability at the interface - explain the effect of surfactants on the stability of colloidal systems - explain the models and parameters for estimation of components miscibility in the products optimization
3.Rheology of complex fluids and products in function of formulation engineering	- to recognize the influences rheology in product engineering - to apply the rheometry techniques in quality control and product formulation	- using equations define and explain the rheological behavior of different fluids and connect them with application properties - explain the results of rheological measurements of the product
4. Formulation and properties of selected products (emulsions, dispersions, suspensions, foams and powders)	- to analyze the elements of the process of formulation (*in situ, ex situ*) that affect the stability of multiphase systems and the properties of the product - to adapt the formulation for the final purpose by additives - to design of the formulation of powders, granules and agglomerates in the function product application	- define and explain the factors that affect the stability of multiphase systems, depending on the selection of stabilizer - enumerate types of additives in relation to the role in the formulation - connect the modes and mechanisms of agglomeration and properties of the product

	- to design s processes in the function of product engineering	- give examples of operations (mixing, grinding, dispersion, emulsification, agglomeration, flocculation, drying) in a discontinuous batch process of products formulation
5. Functional properties of products	- to integrate and apply the methodology of product engineering for value-added product or a new product (multi-level approach, functional properties, quality factors, structural features, function application)	- outline the concept of the new products in case studies (detergents, pharmaceuticals, pigments and color cosmetic and agricultural products, food, etc.)

FORM 2

1) Course teachers: Prof. Felicita Briški PhD
Associate. prof. Ana Lončarić Božić PhD

2) Name of the course: Industrial wastewater treatment

3) Study programme: 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. the ability to understand the water quality requirements and analyse the characteristics of industrial wastewaters 2. the ability to define treatment processes and process equipment, and to determine key input and output variables for specific industrial wastewaters. 3. the ability to outline the process flow diagram for wastewater treatment processes 4. the ability to apply integrated strategy of wastewater management	1. the ability to analyse and optimise wastewater water treatment processes ; 2. the ability to understand and assess the feasibility of wastewater treatment processes to meet desired needs within realistic technological, environmental, economic, and health and safety constraints 3. the ability to manage industrial wastewater treatment processes. 4. the ability to identify opportunities and leverage advances in research and development in the field of industrial wastewater treatment

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**
1. Characterization of industrial wastewaters; sources and effects of different water pollutants and their influence on effectiveness of selected wastewater treatment process.	- define physical, chemical and biological characteristics of wastewaters and their potential impact on receiving water bodies - select key chemical and physical indicators of wastewater pollution - classify the stages of wastewater treatment, treatment processes and main types of water pollutants	- explain the influence of suspended and dissolved organic water pollutants on quality of receiving water bodies - specify the characteristics and understand the importance of sum water quality parameters COD and BOD_5 in water analysis, calculate COD/ BOD_5 ratio - determine appropriate

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		sequences of water treatment stages and processes regarding the type of waste water pollutants
2. Physico- chemical and biological wastewater treatment processes, process equipment, and sludge management	- apply physico-chemical and biological processes for wastewater treatment - define process variables and process equipment for wastewater treatment -outline the process flow diagram for physico-chemical and biological wastewater treatment - list and overview the main characteristics of methods for the treatment and disposal of sludge generated in wastewater treatment processes	- propose, outline and describe the process flow diagram for the treatment of wastewater based on given water quality parameters -perform the mass balance for the given processes and propose the appropriate process equipment set-up -explain Monod equation for stationary and non-stationary phases of wastewater treatment processes -select the appropriate sludge treatment method based on the given example
3. Wastewater management strategy	- identify national legislation relevant for the wastewater treatment and water quality regulation and standards	-outline advanced water management system based on principles of economic viability and sustainability

FORM 2

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

2) Name of the course: Solid and Hazardous Waste Treatment

3) Study programme (undergraduate, graduate): graduate

4) Status of the course: obligatory

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

1. to collect the basic knowledge related to the terminology, division and basic data on waste
2. to define of the physical, chemical and biological processes in waste treatment
3. to describe the technology of waste treatment and disposal of solid waste
4. to assemble the legislation on the protection of environmental components in the engineering planning
5. to collect and understanding of the basic knowledge related to the terminology, synthesis, chemical composition, structure, production and properties of polymers
6. to understand the basic knowledge related to the technology of processing and recycling of polymeric materials
7. to work independently in the chemical and physical laboratory
8. to self-presentation and interpretation of laboratory results in written and oral form

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

1. to use basic professional knowledge in the field of waste management
2. to analyze and estimate an integrated waste management system
3. knowledge of various kinds of materials and technologies for their recycling
4. the ability to create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering

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

Teaching unit	**Learning outcomes**	**Evaluation criteria**

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1. Introduction to basic data on waste	- to define the types of waste - to define specific categories of waste - to indicate the recovery and/or disposal of waste - to assemble the legislation and planning documents related to the issue of waste management	- distinguish waste according to place of generation and properties - recognize regulations related to special categories of waste - distinguish between material and energy recovery and estimate the possibilities of waste disposal - use of legislation in the field of waste management
2. Waste treatment	- to explain the mechanical - biological waste treatment (MBT) - to explain the thermal treatment of waste - to indicate the possibilities of advanced methods of waste treatment - to assemble the legislation and documentation relating to the procedures for the treatment of waste	- interpret basic ways of waste treatment - distinguish physic, chemical and biological processes of waste treatment - explain the criteria for the application of more advanced methods of waste treatment - use of legislation in the field of waste management
3. Disposal of residues from waste treatment	- to indicate the procedures for the treatment of flue gases and disposal of waste products - to define the categories of landfills - to indicate the possibilities remediation of contaminated soil - to assemble the legislation and documentation related to the procedures of processing residue from waste treatment	- indicate procedures for the treatment of flue gases and the possibilities of recycling and disposal of waste products - distinguish categories of landfills and explain the criteria for acceptance of waste at landfills - assemble of the potential remediation of contaminated soil - use of legislation in the field of waste management

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4. Introduction to Polymer Chemistry	- acquisition of knowledge about the synthesis processes, chemical composition, the structure of the polymers and the impact on the final properties of materials	- distinguish the synthesis processes to obtain different type of polymers - explain the structure properties relationship
5. Polymer waste stream, advantages and disadvantages of polymer materials	- acquisition of knowledge and understanding of the types of polymeric materials in the application, their collection, the pretreatment processes, secondary raw materials for recycling	-distinguish the type of polymer waste - indicate the procedures and processes of polymer pretreatment
6. Recycling of polymeric materials	- acquisition of knowledge and understanding the mechanical, chemical recycling and energy recovery of polymer waste	- distinguish the technological processes for recalling plastics - indicate procedures for recycling of different polymers

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<table>
<tr><td colspan="2">1) Course teacher: Prof. Sanja Papić, PhD, Prof. Ana Lončarić Božić, PhD, Prof. Zlata Hrnjak-Murgić, PhD</td></tr>
<tr><td colspan="2">2) Name of the course: Technology of Dyes and Coatings</td></tr>
<tr><td colspan="2">3) Study programme (undergraduate, graduate): 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.explain the basic concepts of color and coloration theory
2.describe the processes of production of selected organic dyes and pigments
3. to adopt the knowledge of the application field of dyes and coatings respect to their characteristics
4. acquisition the ability to correlate the structure and properties of components with their role in coatings
5. be familiar with the process of production of coating materials and the impact of key parameters on the application properties of the final products
6. knowing the natural and synthetic binders for paints and their application
7. acquisition of the skills of independent work safely in chemistry lab.</td><td>6) Learning outcomes at the level of the study programme:
1. the ability to design a system or process to meet desired needs within realistic constraints, such as economics, environmental, health and safety, manufacturability and sustainability;
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 create solutions and independently solve problems (including the identification and formulation of the problem) in materials science and engineering</td></tr>
</table>

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

Teaching unit	Learning outcomes	Evaluation criteria
1. Organic synthetic dyes	- explain the basic concepts of color and correlations between the chemical structure of organic compounds and their color (coloration theory)	-understand the basic concepts of color -explain the coloration theory - know the classification of dyes

	- state the areas of application and classification of organic dyes	- list the chemical and the application groups of dyes and know their characteristics - know the application fields of colorants (organic dyes and pigments)
2. Synthesis of organic dyes and pigments	-describe the processes of production of selected organic dyes and pigments	-known the intermediates in the production of dyes -know the method of production (synthesis) of selected dyes from important chemical classes - describe processes of production of selected dyes including an understanding of chemical reactions, a process flow diagram and process conditions - understand the optimization of the synthesis of organic pigments, physical conditioning operations, the impact of crystal structure and particle size on the their application properties
3. Components of coating materials	- understand the correlation between the properties of coating materials and their applicability - correlate the structure and properties of specific components and their role in coating material	-classify coating materials and specify main components and their role in coating material - explain the influence of structure and properties of pigments and fillers on application properties of coating materials -list the main representatives

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		and the production methods of particular types of pigments and fillers in coating materials - classify the main types of additives and explain their role in coating materials -explain the theoretical background and specific requirements for solvents in coating materials
4.Production and application of coating materials	- understand the production and application processes of coating materials - understand the influence of key production process parameters on application properties of coating materials	-outline and explain the production process of coating materials - describe the application processes for coating materials on different surfaces - specify and explain the standard methods for coating materials and dry film testing
5. Methods of binder synthesis	- to adopt the knowledge about the synthesis, chemical composition, structure, production, properties and application of synthetic binders (polymers) in coatings	- to distinguish the various synthesis processes of binders - to distinguish the structure properties relationship and the importance for the application - to work in the laboratory for quality control
6. Binders for paints and varnishes	- to adopt the knowledge about the natural binders: natural resins, natural oils, cellulose derivatives, - - to adopt the knowledge about the synthetic binders: polyester resins, acrylic, amide, polyurethane, phenolic	- to explain the way of manufacturing of the natural binders - to explain the connections of structure properties relationship and the application: outdoor and indoor application, primaries and finishing coatings

FORM 2

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

University of Zagreb
Faculty of Chemical
Engineering and Technology

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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):	**6) Learning outcomes at the level of the study programme:**
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	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 polymer chain structure and of molecular weight	-to interpret polymerization processes -to distinguish different type of polymerizations -to recognize the type of condition and type of structure that is formed

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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

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