10-01 Course description	
Name of the course	***Methodology of scientific research (2 ECTS)*** ***- teachers: Lažnjak, J.; Vlahović, I.***
Goals of the course	- introduce students to basic elements of scientific research; - demonstrate basic concepts and definitions of science; - demonstrate principles, rules and criteria of research; - present changes in social role of science and importance of innovation and commercialization of knowledge; - introduce students to importance of public understanding of science and science communication; - demonstrate elementary skills and knowledge for writing and publishing scientific article; - introduce students to principles of academic ethics and intellectual property rights.
Expected learning outcomes (levels 8.2)	- to define elementary terms of scientific research; - to describe and explain main phases of research process; - to analyze procedures and activities within main phases of research process; - to distinguish key features of the change of science social functions in knowledge-based society; - to compare basic characteristics of professional and scientific research; - to critically evaluate scientific and professional work, critically assess quality of publications using good and bad quality exemplary articles; - to search, analyze, and classify various bibliographical sources; - to distinguish ethical rules in scientific and professional research and publications; - to apply acquired skills in process of thesis application; - to apply competencies and skills in writing and publishing articles.
Course content	Concept and definition of science. Characteristics of science. Structure of science. Categories of scientific research. The difference between professional and scientific work. The importance and role of science in contemporary society. Change of science role and commercialization of research. Knowledge-based society / knowledge based economy and the role of innovation. Methodology of scientific research. General methods in science and logic of scientific research. Specific methods in scientific research. The process and structure of the scientific research. Science communication. Public understanding of science and popularization of science. Writing and publishing research article. Plagiarism and intellectual property protection.
Method of instruction	Lectures (0,5 ECTS), Literature study (1 ECTS), Writing paper (0,5 ECTS)
Evaluation of student performance	Evaluation of written assignment and oral exam

20-H01-1 Course description	
Name of the course	***Surface geophysical exploration and well logging – Unit 1: Surface geophysical exploration (6 ECTS)*** ***- teacher: Šumanovac, F.***
Goals of the course	– Present surface geophysical research methods and their application in hydrogeological, geotechnical and engineering explorations, – Explain physical principles of seismic, gravity, magnetic and electromagnetic methods, – Explain the advantages and limitations of the surface geophysical methods, – Demonstrate basic and advanced interpretation methods. – Explain and present the interpretation process.
Expected learning outcomes (level 8.2)	– Classify and distinguish surface geophysical exploration methods, – Define exploration procedure (selection of geophysical methods and order of measurements) in solving specific hydrogeological, geotechnical and engineering problems, – Apply geophysical modelling, – Analyze and synthesize interpretation results, – Integrate geophysical model with other data (geological, petrophysical, etc.).
Course content	High-resolution seismic reflection method (HRS method). Instruments and equipment. Data acquisition and data processing. Interpretation. Cross-hole seismic measurements. Three-dimensional (3D) seismic method in engineering explorations. Seismic tomography. Advances in seismic reflection and refraction methods. Application of seismic methods in hydrogeological, geotechnical and engineering explorations. Electrical exploration. Vertical and horizontal resolution of the method. Surface electrical resistivity tomography: theoretical basis, multi-electrode systems, measurement geometry, design of data acquisition, two-dimensional (2D) and three-dimensional (3D) explorations, data processing and interpretation, application. Dual gradient mapping and TUBEL method. Magnetotelluric and electromagnetic measurements and data interpretation. GPR measurements. Possibilities of electrical methods in karst explorations. Gravity methods. Remote gravimetric exploration. Gravity exploration in wells. Microgravity exploration: design of the survey, gravity corrections and interpretation. Gravity exploration of underground cavities. Magnetic and aeromagnetic explorations. Quantitative data interpretation. Application of magnetic methods. Complex geophysical explorations.
Method of instruction	Lectures and consultations Exercise (field, computer lab) Seminar
Evaluation of student performance	Evaluation of seminar paper, oral exam.

20-H01-2 Course description	
Name of the course	***Surface geophysical exploration and well logging – Unit 2: Well logging methods (4,5 ECTS)*** ***- teacher: Orešković, J.***
Goals of the course	Presentation of the principles of selected well logging methods depending on the student's field of research, Explain the physical principles of various well logging methods and their use, advantages and limitations, Explain methods of data processing and interpretation, Demonstrate machine learning methods used in the analysis of borehole logging data.
Expected learning outcomes (level 8.2)	– Analyze standard well logs and specialty measurements, – Evaluate the quality of data, – Develop logging program to solve a specific problem, – Analyze well logging interpretation results, – Correlate well logging measurements with geophysical surface measurements, – Relate the log interpretation results to geological model.
Course content	**Well logging methods** Underlying physical principles of well logging methods: acoustic and electromagnetic wave theory, radioactivity (absorption of neutron and gamma-rays), theory of nuclear magnetic resonance (Larmor frequency, relaxation phenomena). Measurement methods: resistivity logging, radioactive methods, acoustic logging and other methods. Magnetic resonance imaging (NMR). Borehole imager (microresistivity imager and acoustic borehole imager), diplog. Well logging in unconsolidated and fractured formations for hydrogeology and engineering geology. Corrections of measurement data, interpretation of different types of borehole logs and determination of petrophysical parameters. An introduction to interpretation software (e.g. Interactive Petrophysics). Application of machine learning methods (supervised and unsupervised) to improve the quality of input data (e.g. prediction of missing logging data) and to automate the processes of data interpretation.
Method of instruction	Lectures and consultations Exercise (computer lab)
Evaluation of student performance	Assessment of practical work, oral exam.

20-H01-3 Course description	
Name of the course	***Surface geophysical exploration and well logging – Unit 3: Geophysical modelling (4,5 ECTS)*** ***- teacher: Šumanovac, F.***
Goals of the course	– Explain and demonstrate the interpretation procedure, – Present 1D, 2D and 3D forward and inverse modelling, – Present forward modelling of electrical, seismic and magnetotelluric data, as well as gravity and magnetic data, – Explain seismic refraction forward modelling using eikonal equation and seismic ray tracing method, – Explain application of forward modelling in geophysical data interpretation.
Expected learning outcomes (level 8.2)	– Apply inversion and forward modelling to construct geophysical model, – Construct seismic model using eikonal equation and seismic ray tracing method, – Work as part of a team to develop and improve geophysics solutions and software.
Course content	Theoretical fundamentals of mathematical modelling in geophysical exploration. One-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) forward and inverse modelling. Software development. Geophysical forward modelling in gravity and magnetic methods. Geophysical forward modelling in seismic methods. Reflection modelling and inversion. Seismic refraction forward modelling using eikonal equation and seismic ray tracing method. Forward modelling in electric and magnetotelluric methods. Application of forward modelling in geophysical data interpretation.
Method of instruction	Lectures and consultations Exercise (computer lab)
Evaluation of student performance	Evaluation of seminar paper, oral exam.

20-H02-1 Course description	
Name of the course	***Advanced methods in seismic reflection exploration – Unit 1: Seismic exploration (5 ECTS)*** ***- teacher: Šumanovac, F.***
Goals of the course	– Introduce theoretical fundamentals of reflection seismic exploration, – Present seismic survey design, – Introduce advanced interpretation methods, – Explain application of synthetic seismograms in data interpretation, – Explain vertical seismic profiling (VSP) data interpretation, – Explain application of seismic reflection in the hydrocarbon reservoir characterization, – Explain application of forward modelling in geophysical data interpretation.
Expected learning outcomes (level 8.2)	– Determine horizontal and vertical resolution of seismic reflection sections and apply in the geological interpretation, – Classify and distinguish geophysical seismic exploration methods, – Interpret and characterize hydrocarbon reservoirs on the seismic reflection sections, – Analyse interpretation results of the vertical seismic profiling (VSP), – Determine seismic model, – Integrate geophysical model with other geological data.
Course content	**Seismic exploration** Theoretical fundamentals of reflection seismic exploration. Vertical and horizontal resolution. The new instruments and equipment. Seismic survey design: determination of recording geometry and the most appropriate measurement parameters. Data processing. Seismic refraction methods for static correction. Advanced interpretation methods. Application of synthetic seismograms (forward modelling) in data interpretation. Seismic methods between wells. VSP data interpretation. Three-dimensional seismic exploration: recording geometry, field measurements and data interpretation. Application of reflection seismic exploration in petroleum geology and hydrocarbon reservoir characterization.
Method of instruction	Lectures and consultations Computer lab exercise Seminar
Evaluation of student performance	Evaluation of seminar paper and oral exam.

20-H02-2 Course description	
Name of the course	***Advanced methods in seismic reflection exploration – Unit 2: Seismic attributes and AVA-analysis (5 ECTS)*** ***- teachers: Šumanovac, F.; Orešković, J.***
Goals of the course	– Explain application of forward modelling in geophysical data interpretation. – Define complex seismic trace, – Introduce basic seismic attributes and their physical meaning, – Present application of seismic attributes in hydrocarbon reservoir characterization, – Explain AVA-analysis and its application.
Expected learning outcomes (level 8.2)	– Analyse the complex seismic trace, – Classify seismic attributes, – Apply different seismic attributes in the interpretation of seismic reflection data, – Explain theoretical basis of AVA-analysis (Amplitude Versus Angle), – Apply AVA-analysis.
Course content	**Seismic attributes** *Seismic attributes:* theoretical basis, definition of a complex trace, the basic seismic attributes, physical meaning of attributes (reflection strength, instantaneous phase, instantaneous frequency, apparent polarity, etc.), attribute systematization, correlation and visualisation of attributes, seismic attributes in hydrocarbon reservoir characterization. **AVA analysis** *AVA-analysis (Amplitude Versus Angle):* theoretical basis, Poisson ratio influence on the reflection coefficient, detection of gas occurrence, determination of petrophysical parameters.
Method of instruction	Lectures and consultations Computer lab exercise
Evaluation of student performance	Oral exam

20-H03-1 Course description	
Name of the course	***Numerical mathematics and geomathematics – Unit 1: Systems of linear equations and ordinary differential equations*** **(6 ECTS)** ***- teachers: Rajić, R.; Vrbaški, A.***
Goals of the course	**Systems of linear equations** - provide the necessary basic mathematical concepts and results, - present direct methods for solving systems of linear equations, - present iterative methods for solving systems of linear equations with the emphasis on the conditions for the convergence of the method. **Ordinary differential equations** - present initial, boundary and initial-boundary value problems for ordinary differential equations of engineering problems in practice and describe the numerical methods for solving them
Expected learning outcomes (level 8.2)	After completing the learning process, from the chosen topic the doctoral candidate will be able to: **Systems of linear equations** - formulate the basic ideas of individual numerical methods for solving systems of linear equations - compare numerical methods for solving the given problem with respect to their advantages and disadvantages - check the assumptions of the method and solve the system of linear equations by a direct or iterative method - analyze the results of numerical methods **Ordinary differential equations** - formulate the basic ideas of individual numerical methods for solving ordinary differential equations - compare numerical methods for solving the given problem with respect to their advantages and disadvantages - solve ordinary differential equations of simpler mathematical models of engineering problems by a suitably chosen numerical method - analyze the results of numerical methods
Course content	**Systems of linear equations:** Basic concepts and results of linear algebra (eigenvalues and eigenvectors, vector and matrix norms, convergence in vector and matrix norms). Direct methods for solving systems of linear equations. LU factorization, Cholesky factorization, QR factorization. Iterative methods for solving systems of linear equations. Linear iterative methods. Jacobi method, Gauss-Seidel method. Convergence of Jacobi and Gauss-Seidel's Methods. **Ordinary differential equations:** Numerical solving of an initial value problem for ordinary differential equations of the first order. Euler's and Runge-Kutta methods. Numerical methods for solving the system of ordinary differential equations of the first order. Numerical solving of a boundary value problem for ordinary differential equations of the second order. Finite Difference Method.
Method of instruction	Lectures
Evaluation of student performance	Written exam

20-H03-2 Course description	
Name of the course	***Numerical mathematics and geomathematics – Unit 2: Partial differential equations*** **(5 ECTS)** ***- teacher: Jaguljnjak Lazarević, A.***
Goals of the course	- explain the formulation of numerical models (constitutive equations, kinematical relations, compatibility conditions, equilibrium equations, boundary conditions, loads) - describe basic numerical solution methods (Rayleigh-Ritz method, finite element method, discrete element method, finite difference method) - show origins of errors which arise during formulation and calculation of numerical models - explain basic elements (routines) of the computer program (algorithms and pseudocodes) used for realization of numerical methods.
Expected learning outcomes (level 8.2)	After completing the learning process, from the chosen topic the doctoral candidate will be able to: - formulate basic ideas inside certain numerical methods for solving partial differential equations, - write a simple computer program for some numerical methods, - create optimal (simple and sufficiently accurate) numerical model of a real engineering problem, - choose suitable numerical solution procedure, - assess model and solution accuracy.
Course content	From the real (engineering) problem to the numerical model: the concept of material continuum, kinematical relations, compatibility conditions, equilibrium equations, constitutive laws, boundary conditions, loads, linearization, boundary definition. Solution procedures: force method and displacement method. Strong and weak formulation, Rayleigh-Ritz method, finite element method, discrete element method. Properties and sparce ***storage*** of stiffness matrices and solving system of linear algebraic equations. Errors in creating and calculating numeric models. The advantages and disadvantages of discretization procedures.
Method of instruction	Lectures or Consultations and demonstration computer exercise, writing a seminar. Teaching material encompasses textbooks from Croatian and foreign universities, scientific papers and the computer program Wolfram Mathematica
Evaluation of student performance	Evaluation of writing and presenting a student's project.

20-H03-3 Course description	
Name of the course	***Numerical mathematics and geomathematics – Unit 3: Geomathematics*** **(7 ECTS)** ***- teacher: Malvić, T.***
Goals of the course	**Present** the importance of selection of basic statistical procedures in geomathematics. Understand variogram function and its modelling in 1, 2 or 3 dimensions. Know theory and application of geomathematical estimation for one or more variables. **Understand** the role of neural networks in geomathematical analyses. To know the basic idea and principles of networks, its structure, equations, learning. Study the networks with backpropagation, radial function and generalised regression. **Connect** statistical procedures with purpose of describing and selection of input data in useful groups. Link theories of variogram and geostatistical estimations for one or more variables. **Understand** the difference between interpolation and estimation. **Know** the basic Croatian geomathematical terminology.
Expected learning outcomes (level 8.2)	After completing the learning process, from the chosen topic the doctoral candidate will be able to: - **select** geological and generally subsurface data that could be analyzed by geomathematical methods as variogram, Kriging, stochastical simulations, neural networks - **analyze** geological subsurface data using variograms, Kriging, stochastical simulations, neural networks - **review** the proper application of neural networks for subsurface data, especially of different neural functions - **recognise** the situations when networks could be over-trained and meaningless **- explain** the meaning of number of network's hidden layers, activation functions and reasons why to automate network calculations - **distinguish** the data and groups which prefer geostatistical analyses vs. ones appropriate to analyse with neural networks, especially regarding spatial dimensions - **apply** the Croatian geomathematical terminology - **interpret** obtained results from the own researching data and published scientific paper after the exam is successfully passed.
Course content	**Geomathematics:** ***Geostatistics:*** 1. Basic statistical procedures (variance, distributions, co-variance, correlation); 2. Variogram (basic parameters, models); 3. Variogram analysis of data on kilometre distances; 4. Variogram analysis of data on metre and centimetre distances; 5. Theory of geostatistical estimation (properties, matrix equations, Simple and Ordinary Kriging, calculations, regular data set, model without/with nuggets, anisotropy, irregular data set, high anisotropy in dominant dimension, CoKriging, stochastical simulations, transformation of input data, processing of input data, "zero" realisation in simulation, set of realisations, advantages/disadvantages of the sequential Gaussian simulations, inverse distance weighting); 6. Examples of interpolation and simulation using geostatistics; 7. Seismic data as secondary variable; 8. Stochastical simulations – examples. ***Neural networks:*** 1. Basic idea and principles (human neurons, structure of neural network, basic mathematics, learning, backpropagation, radial function, generalised regression); 2. Estimation of clastic facies by neural networks; 3. Estimation of lithology and hydrocarbon saturation; 4. Estimation of porosity; 5. Partial reconstruction of well logs, examples from the Croatian part of the Pannonian Basin System. ***Terminology:*** learning of the Croatian geomathematical terminology in researching and application of geomathematics through different studies and scientific papers. Croatian geomathematical dictionary, Croatian-Croatian

	dictionary with English synonyms.
Method of instruction	The education includes lectures and seminar with computer modelling. Teaching materials exist as university books, several scientific papers, freeware software and measurement devices.
Evaluation of student performance	The students are obligated to make seminar and present results to professor. So, the exam includes written and oral part.

20-H04 Course description	
Name of the course	***Engineering Statistics (10 ECTS)*** ***- teachers: Rajić, R.; Vrbaški, A. (theoretical part); Kuhinek, D.(mining engineering); Malvić, T. (geology); Posavec, K. (geological engineering); Vulin, D. (petroleum engineering)***
Goals of the course	**Statistics – theoretical part** **Analyze** concepts from the application of probability in construction of models for statistical analysis **Introduce** statistical tests for data analysis **Introduce** regression models for examination of the dependence of the characteristics of the observed phenomenon **Present** the application of the programming language R in solving statistical problems **Statistics in Mining Engineering (engineering measurements)** **Present** the use of statistical methods for measurement result analysis, measurement system components calibration results, design of experiments and determination of measurement quality **Demonstrate** result measurement uncertainty calculation. **Present** the use of expert software for automating measurement data analysis. **Statistics in Geology** **Present** importance of selection and editing of input data; know statistical distribution and their application on geological data; often applied statistical tests and correlation, regression and similar tools for description of relations among geological variables. **Connect** the application of surface integration in volume calculations of the subsurface structures. **Statistics in Geological Engineering** **Analyse** measurements, errors and uncertainties in data **Present** distributions, confidence and prediction intervals **Present** methods for time series analysis **Analyse** tools for data analysis in Excel-u® **Present** specifically designed software for time series analysis **Statistics in Petroleum Engineering** **Categorize** variables for production forecasts and optimization **Establish** connection between multiple variables by multivariate analysis for case when observed parameters did not provide good correlation with univariate analysis **Separate** different data sets by discriminant analysis. **Determine** the perspective methods for drilling stimulation and hydrocarbon production enhancement by stochastic methods, and by defining the quality of the prediction **Quantify,** by correlations i.e. linear regression and by outlier definition, the representativeness of petrophysical and/or well-log and/or geomechanical and/or production data
Expected learning outcomes (levels 8.2)	After completing the learning process, from the chosen topic the doctoral candidate will be able to: **Statistics – theoretical part (5 ECTS)** **Apply** an appropriate statistical test for data analysis (without a computer and by using a computer) **Apply** linear and nonlinear regression model or multiple linear regression model when examining the dependence of two or more characteristics of the observed phenomenon (without a computer and by using a computer)

	Interpret the results of statistical methods correctly **Statistics in Mining Engineering (engineering measurements) (5 ECTS)** 1. Design a measurement system (selection of components based on the component properties, 2. Design measurement system verification, 3. Make measurement uncertainty budget of measurement/calibration, 4. Select and use measurement/calibration results data analysis method, 5. Design a Labview VI for automation of measurement system, 6. Design automated data analysis using NI Diadem. **Statistics in Geology (5 ECTS)** **Select** geological and, in general, subsurface data that could be analyzed with statistical tools (above). **Analyzed** measurements errors, determinism and stochastics in subsurface models, correct application of normal, binomial, Poisson, log-normal and uniform distributions). **Review** the correct application of one- and two-tails tests in geology, especially parametric t and F and ANOVA. **Recognize** the importance of linear correlation and its limitations as well as of rank correlations. **Distinguish** prizmoidal, trapezoidal and Simpson formulas in geological structures approximation. **Interpretation** of results obtained by given tools and methods, using own researching data, and publish scientific paper after exam. **Statistics in Geological Engineering (5 ECTS)** - Determine measurement methods and analyze errors and uncertainties in data - Define data distributions with accompanying confidence and prediction intervals - Suggest methods for time series analysis - Perform statistical analysis using tools for data analysis in Excel® - Perform statistical analysis using specifically designed software for time series analysis. **Statistics in Petroleum Engineering (5 ECTS)** - Separate different production intervals by discriminant analysis. - Define the quality of the prediction and analyze stochastically processes in development of hydrocarbon and geothermal energy recovery methods based on fluid and rock parameters in the reservoir and recorded production data. - Determine candidate wells for hydraulic fracturing, based on the basic fluid and rock properties by determining significant variables and by using the fuzzy-logic method. - Determine the probability of the reserves based on the volumetric equation in the function of porosity (so-called P10, P50, P90, i.e. tenth, fifty and ninety percentile). - Define, i.e. statistically predict the composition of hydrocarbons based on measured composition (the generally accepted method is based on the assumption of gamma distribution).
Course content	**Statistics – theoretical part** 1. Statistical tests: a test for comparison of the variances of two samples (F-test); a test for comparison of a sample expectation and a population expectation when the sample variance is known (z-test); a test for comparison of a sample expectation and a population expectation when the sample variance is unknown (t-test); a test for comparison of expectations of two samples (t-test) – unrelated large samples, unrelated small samples, related samples; a test for comparison of a sample

	proportion and a population proportion; a test for comparison of the proportions of two samples; a test of belonging to a distribution (χ^2-test) 2. Regression and correlation analysis: linear regression (regression line, least squares method, confidence intervals for regression line coefficients, testing of the hypothesis about coefficients of regression line); correlation coefficient; nonlinear regression (square, cubic, exponential, power function, rational function); multiple linear regression (regression equation, determination coefficient, corrected determination coefficient) **Statistics in Mining Engineering** Measurement errors of direct and indirect measurements. Determination of minimal number of measurements to achieve wanted reliability of results. Statistical tools for measurement results analysis. Use of MS Excel for statistical analysis (normal and t distribution, descriptive statistics, histogram, regression without and with weighted factors, regression with more independent variables, t-test and F-test for comparison of measurement result repeatability, multicomponent transducer compensation matrix). Assessment of possibility and justification of measurement. Measurement of deformation, displacement, force, pressure, temperature, electrical measurements (voltage, current, resistance, power, energy), acoustical measurements (sound and noise), vibration measurements (displacement, velocity, acceleration). Measurement transducers and their properties (determination from calibration results. Static and dynamic properties and determination using static procedures. Labview software. Automatization of measurement systems. Remote measurement. Analog and digital measurement. Measurement chain. Measurement filters. Coding of digitized measurement data. Properties of devices for acquisition, archiving and analysis of digitized measurement data. Principles of measurement uncertainty calculation with examples. Data analysis using NI Diadem software and data analysis automation. **Statistics in Geology:** 1. Importance of selection and editing of input data (measurement errors, description of geological model using determinism and stochastics); 2. Statistical distribution and their application on geological data (normal/Gauss, binomial, Poisson, log-normal, uniform distribution, measures of central tendency); 3. Often applied statistical tests in geology (t-test, F-test, ANOVA); 4. Correlation, regression and other statistical tools for present relations among geological variables (relations among correlation, standard deviation, co-variance, regression, examples of non-linear connections, ranking correlation coefficients); 5. Surface integration and application in volume calculation of “closed” geological structures (prizmoidal, trapezoidal and Simpson equations and applications); 6. References **Statistics in Geological Engineering** (1) Measurements, errors and uncertainties (measurement methods, random and systematic errors, uncertainty calculation, precision and accuracy in data); (2) Data distributions (symmetric and asymmetric, 68% and 95% confidence intervals, Excel®'s NORMINV() function, Excel®'s NORMSINV() function; (3) Time series analysis: correlation, regression, cross-correlation, trend analysis (linear and nonlinear regression including linear and nonlinear 68% and 95% confidence and prediction intervals, Mann-Kendal test, statistically significant trend); (4) Tools for data analysis in Excel® - Data Analysis Tools: variance, standard deviation, covariance, descriptive statistics, correlation, regression; (5) Specifically designed software for time series analysis: recession analysis, cross-correlation analysis, aquifer recharge analysis, geochemical background analysis (Iterative 2δ technique and Calculated distribution function with application of Lilliefors test) **Statistics in Petroleum Engineering** The engineer who enrolled the PhD study in the field of Petroleum Engineering will be introduced to the chapters of the statistics that have the following titles:

	1. Outlier analysis (and determination of residuals), exclusion of non-quality data, substitution of non-existent data. 2. Univariate analysis and multivariate analysis - variable pair correlations, determination of significant variables. 3. Probability estimation and analysis 4. Linear discriminant analysis 5. Determination of optimal value of independent variables by nonlinear regression 6. Classification of the prediction quality in Reservoir Engineering - Student Residual 7. Basic types of distribution, distribution in petroleum engineering (most common are: normal, lognormal and similar, e.g. gamma). 8. Frequency distribution, graphical representation of probability distribution. Tornado diagram, spider diagram. 9. Measures of central tendencies, data dispersion measures, asymmetry (skewness), shrinkage (kurtosis). Determination of sample population parameters. 10. Analysis using Monte Carlo and Latin Hypercube "sampling" method. In this way, PhD student will prove that he/she mastered the above-mentioned chapters by the preparation of seminar work or by publishing scientific work related to the following specific problems (the student may also suggest a problem closely related to his field of research): 1. Regression of petrophysical data - formation factor as a function of porosity (outliers, correlations, linear regression) 2. Separation of different production intervals (discriminant analysis) 3. Determining the perspective method for Enhanced Oil Recovery based on the basic fluid and rock parameters in the reservoir and the historical performance data of a particular method (stochastic analysis, definition of predictive quality) 4. Determination of wells for hydraulic fracturing based on basic fluid and rock parameters in the reservoir (determination of significant variables, fuzzy logic) 5. Determine the type of porosity distribution from laboratory data and well-log measurements, generate a greater number of data stochastically and determine the likelihood of reserves based on a simple volumetric equation as porosity function (so-called P10, P50, P90, i.e. tenth, fifty and ninety percentile) 6. Prediction of hydrocarbon composition based on measured component fractions. The generally accepted method is based on the assumption of gamma distribution and determination of its parameters (Whitson, C.H., Soreide, I. and Anderson, T.F., 1989. *C7 + characterization of related equilibrium fluids using the gamma distribution)*. Determine the distribution that fits best to the measured composition and, according to distribution parameters, generate a series of random samples for further analysis of thermodynamic fluid behavior. 7. According to production data in a certain production period, determine the production decline curve for future production (decline curve analysis). Exclude the data that, because of a number of factors (bad data acquisition, changes in production regime, production stimulation by hydraulic fracturing, etc.), are the noise in typical output curve trend (outliers, weighted residuals, linear regression, etc.) 8. Determination of pore size distribution based on capillary pressure measurement, dominant pore geometry estimation and relationship of wettability and specific rock composition (multivariate analysis, frequency distribution, distribution and probability diagrams).

20-H05 Course description	
Name of the course	***Principles and application of chemistry in engineering profession*** **(6 ECTS)** ***- teacher: Kapor, F.***
Goals of the course	- Display theory of electrolytic aqueous solutions - Display the activity of aqueous solutions and explain its calculation - Display physical, chemical and biochemical composition of water and purification methods - Display of the chemical composition and methods of environmental analysis
Expected learning outcome (level 8.2)	After completion of the learning process the doctoral student will be able to: - Relate electrolytic nature of water with its properties (1 ECTS) - Recommend a method of water treatment regarding the pollution (1 ECTS) - Recommend the chemical and analytical methods of analysis of the sample with respect to the amount of analyte (1 ECTS) - Recommend a way of neutralizing or removing contaminants from the environment (1 ECTS) - Evaluate the type of corrosion process and suggest adequate protection (1 ECTS) - Predict the selection of materials with respect to the chemical composition of the electrolyte in Petroleum Engineering (1 ECTS)
Course content	The electrolytic nature of water solutions, application of the Debye – Hueckel theory to ionic strength and behaviour of water solutions. Influence of pH, Eh and pT conditions of open and closed water pools on the stability and balance of water solutions, especially carbonate balance (1). The relationship (connection) between enthalpy and free Gibbs' energy and theory influence on the creation of water solutions. Metallic – organic complexes in water solutions (2). Quality standard (3). Radioactivity. Natural radioactivity and artificial radioactivity. Impurities that affect health (4). Pollution processes caused by the human activity and the chemism of pollutants and characterization. Waste and pollutants produced by mining engineering, industry and households (5). Storing, destruction and utilization of solid, liquid and gaseous waste matter. Chemical processes in waste disposal dumps (6). Emission of pollutants into the environment and environmental interaction. Registration and control of the pollutant emission (7). Devices and measuring techniques. Accidental situations in gaining and refinement of mineral resources. Choosing the best method and machinery for the disposal of various waste materials (8). Corrosion processes on metal equipment in drilling, production and transport of oil and gas. Types of corrosion processes, general corrosion, localized corrosion: pitting and crevice, galvanic corrosion, microbiological corrosion, metallurgic influenced corrosion, mechanically assisted degradation, internally and environmentally induced cracking (9). Designing to minimize corrosion. Causes of corrosion: presence of carbon dioxide, hydrogen sulphide, polysulphides, organic acids, oxygen contaminated fluids introduced as drilling mud, water, brines, hydrochloric acid injected to aid formation permeability (10). Some of these fluids are inherently corrosive, others are potentially corrosive when contaminated with oxygen (11). Corrosion control methods, selection of corrosion resistant alloys, protective coatings, application of cathodic protection to oil field equipment (12).
Method of instruction	*Teaching will be conducted through lectures (1 ECTS), a project task that includes laboratory tests (4 ECTS) and preparation of material for publishing a scientific article (1 ECTS).*
Evaluation of student performance	project assignment 70% final exam 30%

20-H06 Course description	
Name of the course	***GIS and databases (5 ECTS)*** ***- teacher: Perković, D.***
Goals of the course	**Introduce** Database Management Systems (DBMS) **Define** relational model and relational database **Present** data modeling, SQL language, and relational algebra **Present** database design **Define** Geographic Information Systems (GIS) **Present** thematic modeling, spatial analysis and visualization **Present** the use of the database in the GIS **Present** geospatial databases and WEBGIS systems
Expected learning outcomes (levels 8.2)	After completing the learning process, the doctoral candidate will be able to: - create conceptual, logical and physical data model based on data analysis (2 ECTS) - design database based on built models and test by entering own data (1 ECTS) - set up database queries and define constraints, security and database protection (1 ECTS) - create a GIS project based on spatial data analysis (1 ECTS) - perform spatial operations and generate cartographic layouts (1 ECTS) - design a geospatial database and WEBGIS system (1 ECTS)
Course content	(1) Database management systems; (2) Relational model data; (3) Data analysis: entities, relations, entity-relationship diagram, attributes and domains, keys, specialization/generalization; (4) Data model development: conceptual model, logical model, physical model; (5) Database design: normalization, referential integrity, redundancy, constraints; (6) Database customization: graphical interface, menus, queries, forms, reports, program modules; (7) Database security and protection; (8) Final stage of development: validation check, documenting, database maintenance, removal of errors, upgrading; (9) Geographic information systems; (10) Basic geospatial features in GIS; (11) Data analysis and spatial operations; (12) Basic cartographic elements and visualization techniques in the GIS project; (13) Structured databases and GIS/CAD systems; (14) Geospatial databases; (15) WEBGIS systems
Method of instruction	*Teaching will be conducted through lectures (1 ECTS), project assignment (5 ECTS) and final written exam (1 ECTS).*
Evaluation of student performance	*Students are required to attend lectures, make a project assignment and present it, and pass a final written exam.* **Lectures *(0 points):*** *1. student presence* ***Project assignment (70 points)*** *1. collecting and reading literature* *2. solving the project task* *3. presentation* **Final exam (30 points):** *1. preparation* *2. written exam*

20-R01-1 Course description	
Name of the course	***Surface exploitation – Unit 1: Surface exploitation of solid raw materials (3 ECTS)*** ***- teacher: Bohanek, V.***
Goals of the course	- demonstrate the development of the methods and technologies of surface exploitation of solid raw materials - display the global market needs and surface producers of solid raw materials – metal ores, coal, non-metalic and construction raw materials - demonstrate the procedure of standardization in surface exploitation of raw materials directed on mining mechanization and procedure of mine reclamation managing of excavated space
Expected learning outcomes (levels 8.2)	Upon completion of the learning process the doctoral candidate will be able to: - formulate the development of the methods and technologies of surface exploitation of raw materials - present the global market needs and surface producers of raw materials – metal ores, coal, non-metalic and construction raw materials - present the procedure of standardization in surface exploitation of raw materials directed on mining mechanization and procedure of mine reclamation managing of excavated space
Course content	***Surface exploitation of solid raw materials*** The methods and technologies of surface exploitation of the raw materials. Particularities of surface exploitation methods in non-metal raw materials deposits. Conditions and surface exploitation methods in the function of preparation of raw materials for further processing. Application of appropriate surface exploitation methods and technology of mineral processing, which protects other resources in the environment (water, air, ground, nature), and reduces the negative impacts to the environment to the lowest possible measure. Selective surface exploitation methods connected to the requirements of satisfying the quality of raw materials for the appropriate industrial processing. Implementation of computer programmes in calculation of raw material reserves, planning and development of mining operations, optimization of production, designing and choice of technology. Reclamation and final redesign of surface exploitation fields of solid raw materials during and upon completion of exploitation. Legal framework for open pits – rules from the area of mining with regards to other relevant regulations of environmental protection, protection of nature and documents referring to zone planning.
Method of instruction	*Lectures* *Seminars*
Evaluation of student performance	*Written exam, mark of seminars work*

20-R01-2 Course description	
Name of the course	***Surface exploitation – Unit 2: Dimension Stone Quarrying and Processing (3 ECTS)*** ***- teachers: Kujundžić, T.; Korman, T.***
Goals of the course	- Define criterions of deposit evaluation of dimension stone - Present of modern ways of opening and development of surface exploitation of deposits and processing methods of dimension stone - Present methods of determining the optimal development direction of open pit - Present theoretical and experimental features of exploitation and processing of dimension stone - Define criteria's for selecting machines and cutting tools, and the conditions and methods of work in exploitation and processing of various types of rocks Present theoretical assumptions of further development of the technology of exploitation and processing
Expected learning outcomes (levels 8.2)	- Formulate value of deposit of dimension stone - Develop a way of opening and development of surface deposit exploitation and processing method of dimension stone - Create optimal direction of open pit development - Generate a choice of machines and cutting tools, as well as conditions and modes for exploitation and processing of various types of rocks - Set up a hypothesis for further development of the technology of exploitation and processing of dimension stone
Course content	***Dimension Stone Quarrying and Processing*** Evaluation of beds, tectonic set, blocks and usability. Contemporary point of view of possibilities of opening and development of surface deposits and processing method of dimension stone. Graphic and calculation methods of determination of the optimum development direction of the pit according to its surface and height. Theoretical and experimental characteristics of stone extraction by means of contemporary methods of sawing and breaking of rocks, laboratory and in-situ testing in various phases of extraction and processing. Criteria of selection of construction and technological parameters of machines and cutting tools and conditions and methods of extraction and processing of various rock types. Theoretical assumptions of possible directions of further development of the technology of exploitation and processing of dimension stone.
Method of instruction	*Lectures* *Laboratory exercises* *Seminars*
Evaluation of student performance	Seminar paper, oral examination, project task

20-R01-3 Course description	
Name of the course	***Surface exploitation – Unit 3: Strategy of raw material management on EU level (3 ECTS)*** ***- teachers: Klanfar, M.; Bohanek, V.***
Goals of the course	**-**Interpret the raw materials global market and EU position -express the goals of European raw materials innovation partnership, -present the status of exploited quantity of crude raw materials by kind on EU level -present the goals and structure pillars of European Strategic implementation plan of raw materials, -present the cases of good practice on management of raw materials in EU (Finland, Ireland, Sweden, Portugal), -interpret the goals and contents of European programmes on raw materials (progammes Horizon 2020, FP7 and others)
Expected learning outcomes (levels 8.2)	-understand relations and situation of raw materials global market and position of EU -present the state of raw materials exploitation in EU **-**be acquainted with goals of European innovation partnership on raw materials as well as EU Strategic implementation plan for raw materials **-** be acquainted with goals and contents of European programmes on raw materials -be acquainted with the cases of good practice on management of raw materials on EU level
Course content	**Strategy of raw materials management at EU level** Opportunity and relations on raw materials global market, state and position of European mining. Goals and the structure of European innovation partnership on raw materials in accordance with goals of European industrial policy. The goals and contents of pillars of European Strategic implementation plan: technological, non-technological and pillar of international co-operation. Goals, contents and results of European programme for raw materials (programmes Horizon 2020, FP7 and others), their similarity and connection. Examples of good practices of mineral policies and raw materials management in EU member state (Finland, Ireland, Sweden, Portugal). Correlation EU mineral policies and raw materials management with circumstances in Republic Croatia.
Method of instruction	*Lectures* *Seminars*
Evaluation of student performance	*Written exam, mark of seminars work*

20-R02-1 Course description	
Name of the course	***Underground exploitation of mineral raw materials – Unit 1: Calculations in ventilation of mines and subsurface openings (3 ECTS)*** ***- teacher: Klanfar, M.***
Goals of the course	- **Demonstrate** the methods for calculation of airflow in underground mines and openings, - **Demonstrate** analysis methods for auxiliary ventilation systems, - **Demonstrate** the methods for dilution time calculation after blasting operation at the excavation face**,** - **Demonstrate** fan characteristic curves and series/parallel fan combinations, - **Demonstrate** survey methods for duct ventilation systems.
Expected learning outcomes (levels 8.2)	- **Determine** the airflow requirements for underground mines and openings - **Calculate** the auxiliary ventilation systems for underground mines and openings - **Calculate** the dilution time requirements for ventilation after blasting operation at the excavation face - **Design** fan characteristic curves and series/parallel combinations for multiple fans - **Perform** ventilation surveys and their methods for duct ventilation systems.
Course content	***Calculations in ventilation of mines and subsurface openings*** Ventilation networks for underground mines and openings. Resistance of airways and ventilation ducts. Ventilation network airflow calculations, relevant equations i calculation examples. Natural ventilating pressure, impact on ventilation network and fan operation. Fan characteristic curves, main and auxiliary fans. Standards and regulations in ventilation of underground mines and openings. Air quality control in the underground mines and openings. Subsurface air conditioning. Occupational health and safety considerations in mining environment. Gaseous products of explosives detonation. Exposures to harmful gases resulting from a blasting operations internal combustion engines. Assessment of a re-entry period duration required to dilute harmful gases below threshold limit values, after the blasting operation. Pressure drop in ventilation ducts of auxiliary systems, theoretical equations and ventilation duct surveys.
Method of instruction	*Lectures* *Exercises* *Seminar paper*
Evaluation of student performance	Oral exam, evaluation of seminar paper

20-R02-2 Course description	
Name of the course	***Underground exploitation of mineral raw materials – Unit 2: Dimension Stone Quarrying and Processing (3 ECTS)*** ***- teachers: Kujundžić, T.; Korman, T.***
Goals of the course	- **Define** criterions of deposit evaluation of dimension stone, - **Present** of modern ways of opening and development of underground exploitation of deposits and processing methods of dimension stone, - **Present** methods of determining the optimal development direction of underground dimension stone quarry, - **Present** theoretical and experimental features of exploitation and processing of dimension stone, - **Define** criteria's for selecting machines and cutting tools, and the conditions and methods of work in exploitation and processing of various types of rocks, - **Present** theoretical assumptions of further development of the technology of exploitation and processing.
Expected learning outcomes (levels 8.2)	- **Formulate** value of deposit of dimension stone - **Develop** a way of opening and development of underground deposit exploitation and processing method of dimension stone - **Create** optimal direction of underground dimension stone quarry - **Generate** a choice of machines and cutting tools, as well as conditions and modes for exploitation and processing of various types of rocks - **Set up** a hypothesis for further development of the technology of exploitation and processing
Course content	***Dimension Stone Quarrying And Processing*** Evaluation of beds, tectonic set, blocks and usability. Contemporary point of view of possibilities of opening and development underground deposits and processing method of dimension stone. Graphic and calculation methods of determination of the optimum development direction of the mine. Theoretical and experimental characteristics of stone extraction by means of contemporary methods of sawing and breaking of rocks, laboratory and in-situ testing in various phases of extraction and processing. Criteria of selection of construction and technological parameters of machines and cutting tools and conditions and methods of extraction and processing of various rock types. Theoretical assumptions of possible directions of further development of the technology of exploitation and processing of dimension stone.
Method of instruction	*Lectures* *Laboratory exercises* *Seminar*
Evaluation of student performance	Seminar paper, oral examination, project task

20-R02-3 Course description	
Name of the course	***Underground exploitation of mineral raw materials – Unit 3: Underground exploitation of solid mineral raw materials (3 ECTS)*** ***- teacher: Galić, I.***
Goals of the course	- **Present** contouring of the deposit (making a geological model) using modern work techniques (computer and applied programs). - **Present** the design of mining underground rooms (using computers and aplication programs). - **Present** the development of underground mining works (the way of opening mines, developing, preparation and excavation of deposits). - **Present** the methods of underground exploitation. - **Present** a methodology for evaluating the success of mining activities and evaluating the value of the expected results of exploration and exploitation of mineral raw materials. - **Demonstrate** the technical-economic analysis of the efficiency (efficiency) of exploitation of mineral raw materials.
Expected learning outcomes (levels 8.2)	- **Create** a deposit template and a map of mineral resources reserves - **Design** of the room opening, development, preparation and excavation of deposits for underground mines - **Propose** a method of underground exploitation of mineral raw materials for certain conditions (criteria) - **Analyze** the impact of underground exploitation on the environment and propose ways of rehabilitation - **Create** a model of technical-economic analysis of the efficiency (efficiency) of underground exploitation of solid mineral raw materials
Course content	**Underground exploitation of solid mineral raw materials** Exploration of mineral raw materials from surface and underground mining works. Creating a geological model and enclosing a deposit (computer and applied programs). Limiting the exploitation field and determining the size of the excavation units (horizontal and vertical space distribution). Classification and design of mining underground rooms (using computers and application programs). Development of underground mining works (opening, elaboration, preparation and excavation). Methods of underground exploitation of mineral raw materials. Deformation of the surface as a result of underground exploitation (environmental impact. Methods of performance evaluation and technical-economic analysis of the efficiency (efficiency) of underground exploitation of mineral raw materials.
Method of instruction	*Lectures* *Seminar*
Evaluation of student performance	Oral exam, the evaluation of the seminar work.

20-R03 Course description	
Name of the course	***Design of mining works (5 ECTS)*** ***- teacher: Galić, I.***
Goals of the course	**Present** the methodology of mining projects. **Demonstrate** applied computer programs for mining projects. **Present** forecasting methods and strategic planning of mineral raw materials management **Demonstrate** forecasting and strategic planning of mineral raw materials management in the Republic of Croatia. **Present** the bases for designing exploration and exploitation of mineral raw materials. **Demonstrate** the methodology of deposit research and access to the determination of reserves of mineral raw materials with graph-analytical solutions and integral approach. **Demonstrate** the way of making technical (project) documentation on exploration of mineral raw materials **Present** models (design of contours) of surface and underground mines with comparative analysis of choice of mode of exploitation. **Present** the way of opening and development of mines with the composition of mining works. **Demonstrate** the opening and development of mines according to the type of mineral raw material **Present** exploitation methods with a special focus on the analysis of the impact of mining works on the environment and acceptable solutions. **Present** the approaches in technical rehabilitation and conversion of mining space, with graphical, analytical and / or numerical models. **Demonstrate** simulations of technical rehabilitation and conversion of mining space **Present** a methodology for evaluating the success of mining activities and evaluating the value of the expected results of exploration and exploitation of mineral raw materials. **Demonstrate** the way of making technical (project) documentation for the execution of mining works (research projects, study solutions and exploitation projects)
Expected learning outcomes (levels 8.2)	**combine** mining engineering design methods (0,5 ECTS) **present** computer programs for mining projects (0,5 ECTS) **critically evaluate** forecasting and strategic planning of mineral raw materials management (0,5 ECTS) **present** methods of exploration of mineral raw materials from the surface and from underground mining works (0,5 ECTS) **critically** evaluate methods of exploitation of solid mineral raw materials (0,5 ECTS) **design** layouts and mining works (0,5 ECTS) **to present** project design solutions for mining works (0,5 ECTS) **critically** evaluate the impact of mining jobs on the environment (0,5 ECTS) **present** methods of technical rehabilitation (0,5 ECTS) **Create** an economic model of efficiency (efficiency) of mining works (0,5 ECTS)
Course content	Methods of designing in mining. Application of computer programs in research and exploitation and determination of surface and underground exploitation parameters. Professional backgrounds for design. Forecasting and Planning in Mining. Making strategic decisions. Mining and geological studies. Spatial planning (municipal, city, county, state). Planning and design of mining works. Planning and designing of investigative works. Approaches to exploration of mineral raw materials. Methods of calculating reserves of mineral raw materials. Presentation and analysis of technical (project) documentation on the exploration of mineral raw materials. Approaches to the design of surface and underground exploitation of mineral raw materials (dimension stone, stone for construction, bauxite and other metal ore, gypsum, clay, carbonate raw materials for industrial processing, cement, coal, etc.): place and the way of

	opening, developing mining works and shaping the dough, dynamics and time schedule. Criteria for selecting the method of exploitation of mineral raw materials by location of mining works (surface or underground exploitation). Geometric analyzes of phase and end contours of mining facilities and different types of budget, from project parameters, volume of materials, costs, production prices, to scientific projections and estimates (examples for certain mineral raw materials). Modeling the organization of work. Remediation of mine and environment (regular and extraordinary). Possible improvements and innovations in mining in terms of efficiency and environmental protection. Techno-economic analysis (rating) of efficiency (efficiency) mode of exploitation. Presentation and analysis of technical (project) documentation on exploitation of mineral raw materials.
Method of instruction	***Set LO: Design of mining works (5 ECTS)***
	Lectures (3 ECTS) *The seminar-presentation (2 ECTS)*
Evaluation of student performance	Students are required to create computer simulation of project solutions and execution of mining works and to prepare seminar work. Students will present simulations and seminars in front of colleagues and teachers. The exam consists of a written and oral part. Within the written part of the exam the student will analyze the methods of exploitation according to the given project assignment. Within the oral part of the exam the student should answer the questions of the subject matter.

20-R04 Course description	
Name of the course	***Optimization of mechanization of mining and geotechnical works (8 ECTS) - teachers: Kujundžić, T.; Korman, T.***
Goals of the course	- Present design and technological concepts of mining machinery and environmental and spatial planning features of mining transport systems as well as the trends of their development - Process specifications, features, level of modernity, reliability and economy of machinery and mining transport systems - Present examples of harmonization of machinery and transport systems with particular technology of mining operations - Define criteria and methods of selection of mining machinery and mining transport systems - Present possibilities of mining machinery working conditions simulation and optimization of transport systems
Expected learning outcomes (level 8.2)	- Formulate technical specifications, features, level of modernity, reliability and economy of machinery and mining transport systems (1,5 ECTS) - Kujundžić - Integrate machinery and transport system to a specific technology of mining operations (1,5 ECTS) - Kujundžić - Generate a selection of machinery and mining transport system (1,5 ECTS) - Korman - Set goals of mining machinery working conditions simulation (1,5 ECTS) - Korman - Optimize mining transport system (2 ECTS) - Kujundžić, Korman
Course content	Various constructional and technological concepts of mine mechanization used for exploitation, loading and construction of underground rooms and tunnels. Development and maturing of specific concepts, contemporary status and trends of development in near and far future, theoretical considerations. Technical characteristics, possibilities, level of contemporariness, reliability and efficiency of certain type or kind of mechanization. Technological adjustment of mechanization to a particular technology of specific mining operations. Criteria and methods of selection of mining mechanization. Possibilities of mine mechanization working conditions simulation in immediate and wider surroundings. Mine transport systems, their technological, economic, ecological, spatial planning and other characteristics. Role and influence of transport on production capacity and usability of mineral resources. Traditional and contemporary methods of planning of underground and surface transport, ranking criteria, alternative solutions. Criteria of selection and evaluation of the operation of a specific transport system. Optimization of various transport types.
Method of instruction	Lectures with discussion (3 ECTS) Laboratory exercises (3 ECTS) Seminar (2 ECTS)
Evaluation of student performance	Seminar paper, oral examination, project task.

20-R05-1 Course description	
Name of the course	***Explosive civil application and blasting methods – Unit 1: Modelling and modern application of explosive processes (4 ECTS)*** ***- teacher: Dobrilović, M.***
Goals of the course	- **demonstrate** theory of shock waves formation and the Renkine-Hugoniot conservation equations - **demonstrate** principles, development and application and the CJ and the ZND models of ideal detonation, reaction zone structure and parameters, and isentropic expansion of detonation products - **demonstrate** the causes of the non-ideal detonation behavior, theoretical models for describing the non-ideal detonation, and application of thermochemical computer codes for theoretical calculation of detonation parameters - **demonstrate** influence of detonation parameters of explosives on effects of explosion on surrounding medium - **examine** rock fragmentation prediction models and **analyze** specific blasting calculation methods
Expected learning outcomes (level 8.2)	- **classify** and present types and application of explosive processes - **associate** basic assumption of different explosive theories - **associate** theoretical assumptions with explosive process application - **predict** explosive materials behavior according to composition and reaction conditions
Course content	Review of basic terms of energetic materials; explosive chemical reaction, detonation, combustion, deflagration. Shock waves; description of shock waves, shock waves model, shock waves formation mechanism, Renkine-Hugoniot jump conservation equations. Detonation; physical model of detonation, the CJ and ZND ideal detonation models;. Deviation from the ideal detonation model. The Wood-Kirkwood model of non-ideal detonation.. Detonation properties of standard explosives. Energy of detonation products. Effects of shock wave. Blasting and brisance capacity of an explosive, metal plate acceleration and the Gurney model. Application of the energy of explosives. Numerical modelling of explosives and propellants,. Modeling of effects of the detonation. Theoretical principles and examples of civil application of explosives energy for metal welding, hardening, deformation, cutting, powder compaction, polymorphic transformation in materials. Explosive energy transition from a borehole, fragmentation and blasting theories.
Method of instruction	Course consists of lectures, exercises and consultations and individual research project, laboratory and field researches
Evaluation of student performance	Oral exam and project assignment - seminar *Students are obliged to complete and solve project assignment, that is a seminar, and present it in front of colleagues and professors. Oral exam consists of set of questions from teaching materials.*

20-R05-2 Course description	
Name of the course	***Explosive civil application and blasting methods – Unit 2: Advanced methods of testing and environmental impact of explosive processes (3 ECTS)*** ***- teachers: Bohanek, V.; Škrlec, V., Stanković, S.***
Goals of the course	- **examine** fracture rock theories and analysis calculation methods of blasting parameters. - **examine** rock fragmentation prediction models and - **analyze** specific blasting methods of advanced initiation systems and explosives. - **identify** methods of assessment and protection against the adverse effects of blasting - **identify** test methods for explosives
Expected learning outcomes (level 8.2)	- **propose** explosive testing methods - **develop** blasting methods in special condition - **predict** fragmentation of blasted rock - **develop** of environmental protection methodology
Course content	Methods of testing the properties of explosives. Laboratory test methods. Model test method. Field test methods. Standardization of explosive substances Harmful effects of mining on the environment and measures to reduce the impact. Seismic effects of mining, air shock wave and noise, ejection of blasted material. Optimization and design of blasting works. Application of advanced initial systems and explosives, simulating the dynamics of mining and forecasting the fragmentation of blasted rock mass
Method of instruction	Course consists of lectures, exercises and consultations and individual research project, laboratory and field research
Evaluation of student performance	Oral exam and project assignment - seminar *Students are obliged to complete and solve project assignments, that is a seminar, and present it in front of colleagues and professors. The oral exam consists of a set of questions from teaching materials.*

20-R06-1 Course description	
Name of the course	***Construction of underground structures, tunnels and repositories for radioactive waste – Unit 1: Excavation and support of underground chambers and tunnels (4 ECTS)*** ***- teachers: Dobrilović, M.; Bohanek, V.; Stanković, S.***
Goals of the course	**EXCAVATION AND SUPPORT OF UNDERGROUND CHAMBERS AND TUNNELS** **identify** types of underground chambers and excavation methods **demonstrate** standard, machine and special excavation methods for tunnels and underground chambers **demonstrate** support systems and methods for horizontal, vertical and a slope chambers **demonstrate** methods and machines for partial and full face excavation **identify** types and properties of materials for primary and secondary support systems **examine** theoretical and numerical methods for support load capacity determination
Expected learning outcomes (levels 8.2)	**classify and present** types of underground chambers excavation methods, **associate** rock mass properties and excavation method **propose** measurement program for the excavation influence determination **propose** excavation method and **design** working cycle **design** support system
Course content	**EXCAVATION AND SUPPORT OF UNDERGROUND CHAMBERS AND TUNNELS** Underground chambers in mining and for other purposes. Standard and special methods of excavation for horizontal, vertical, and aslant chambers. Special shaft and tunnel excavation methods in soils. Injection methods, freezing methods. Drilling of water ground layers. Underground chamber and tunnels excavation by blasting Advanced blasthole drilling methods, electronic initiation system application. Application of emulsion explosives prepared on the field, chemical matrix sensitization. Contour blasting. Transportation solutions, machines, and systems for excavated material transport. Full profile and segment machine excavation. Hard rock, soft rock, and water saturated rock excavation. Full profile excavation machines working principles. Support system and support design methods. Micro tunneling. Carst excavation specificity. Measurements methods of blasting influences on support system. Instruments and seismic influences measuring methods. Influences of blasting measuring methods. Explosive mass calculation methods. Theory and application of yielding support. New Austrian tunneling method of support and excavation. Field experience and examples
Method of instruction	*Course consists of lectures, laboratory exercises and seminar). As a part of the seminar, student will have to solve problems independently on given subject and solve project assignment and produce a seminar. As a part of the lecture, student will be given lecture materials, activity workflow and will have the opportunity to discuss problems related to the project assignment.*
Evaluation of student performance	*Project assignment/seminar in the field of excavation and support of underground chambers and tunnels, presentation of the seminar in front of colleges and professors. Oral exam with questions and problems from teaching materials.*

20-R06-2 Course description	
Name of the course	***Construction of underground structures, tunnels, and repositories for radioactive waste – Unit 2: Tunnelling (3 ECTS)*** ***- teacher: Škrlec, V.***
Goals of the course	**TUNNELING** **demonstrate** classic and modern tunnel excavation methods, **demonstrate** methods and machines for full face tunnel excavation, **demonstrate** the interaction of the rock massif, the underground system, and the lining of the tunnel, **identify** types and properties of building materials for primary and secondary tunnel support systems, **examine** theoretical and numerical methods for tunnel support load capacity determination, **examine** the stress calculation method at the tunnel opening, **examine** New Austrian tunneling method and Norwegian tunneling method.
Expected learning outcomes (levels 8.2)	**propose** tunnel support system monitoring program, **develop** environmental protection methodology, **develop** a program for measuring the convergence and deformations of the rock and support system, **predict and solve** possible problems during tunnel excavation.
Course content	**EXCAVATION AND SUPPORT OF UNDERGROUND CHAMBERS AND TUNNELS** Basic concepts in tunnel construction. Classical and modern excavation techniques. Special tunneling methods (injection, freezing and drilling methods for water-bearing rock). Full profile and segment machine excavation. Tunneling in hard, soft, and water-bearing rock. Full profile excavation machines working principles. Machine excavation field experience in Croatia and worldwide. The method of reinforcing the primary substructure. Methods for measuring the behavior of the primary substructure. Calculation of the primary substructure according to the expected convergence. The method of reinforcing the end face. Substructure and final coating of the profile. Elements of the primary substructure: shotcrete, steel anchors, reinforcing mesh, steel arches and lattice girders. Materials of the substructure: concrete and steel. Theoretical and experimental determination of the load-bearing capacity of the elements of the underground system. Static treatment and guidelines for the calculation of elements of underground systems. Basic principles of bearing capacity calculation according to the limit state method. Representative, characteristic, and budgetary value of impact and bearing capacity. Partial safety factors. Special features of tunnel excavation in karstified carbonate rock. The theory of compliant bedding and its application. Application of computer programs in stress analysis. The new Austrian tunnel method and the Norwegian tunnel method.
Method of instruction	*Course consists of lectures, laboratory exercises and seminar). As a part of the seminar, student will have to solve problems independently on given subject and solve project assignment and produce a seminar. As a part of the lecture, student will be given lecture materials, activity workflow and will have the opportunity to discuss problems related to the project assignment.*
Evaluation of student performance	*Project assignment/seminar in the field of excavation and support of underground chambers and tunnels, presentation of the seminar in front of colleges and professors. Oral exam with questions and problems from teaching materials.*

20-R06-3 Course description	
Name of the course	***Construction of underground structures, tunnels and repositories for radioactive waste – Unit 3: Construction of deep geological repositories for radioactive waste and spent fuel (3 ECTS)*** ***- teacher: Veinović, Ž.***
Goals of the course	– Define the site selection criteria and methodology for deep geological repositories (DGR) of radioactive waste (RW) and spent nuclear fuel (SNF) – Present the concepts of DGR – Present the technologies for construction of DGR – Explain the types and properties of engineering barriers and their changes over time – Demonstrate ways of transport of engineering barrier breakdown products and radionuclides through the geological environment (GE) – Show the ways of creating models of radionuclide transport and models of thermo-hydro-mechanical changes in GE – Assess the durability of DGR and engineering barriers over time – Present the role of natural and anthropogenic analogues – Present the stakeholder engagement program.
Expected learning outcomes (levels 8.2)	- Select the location for the disposal of RW and SNF, - Design security and safety systems at DGR, - Generate numerical models with initial and boundary conditions for specific cases of radionuclide migration and thermo-hydro-mechanical changes, - Propose analytical or numerical methods for solving mathematical models, - Create a communication program with stakeholders.
Course content	Properties and processes of changes and effects of RW and SNF on materials, environment and biota. DGR site selection. Design and alternative concepts of DGR. The concept of multiple engineering barriers. Design and use of underground research laboratories. Selection of appropriate GE according to structural characteristics. The technology of making underground spaces as parts of a DGR. Optimization of radioactive material transport technology in the DGR. Ways of installing cannisters in host rock and technology of filling excavated spaces. Selection, design optimization and modeling of the evolution of the composition of filling materials. Modeling of material changes of engineering barriers with time and transport of radionuclides through engineering barriers and the GE. Thermo-hydro-mechanical analysis in the GE using the finite element method. Communication with stakeholders.
Method of instruction	Course consists of lectures/consultations, after which the student will continue with application of specialized software through analysis of examples from practice and case studies from scientific publications.
Evaluation of student performance	Produce materials/report ready for publishing in scientific journal.

20-R07-1 Course description	
Name of the course	***Laboratory and field research methods in mining and geotechnics – Unit 1: Laboratory and field research methods in soils (5 ECTS)*** ***- teacher: Domitrović, D.***
Goals of the course	- connect the various features of soils and raw materials with appropriate laboratory and field tests in soil mechanics, - demonstrate the planning and execution of research, - present the interpretation, analysis and application of research results, - present the role of research in the various stages of planning and execution of mining and geotechnics, - present the importance of various factors and processes that can affect the quality of research results
Expected learning outcomes (levels 8.2)	- analyze the laboratory and field research methods of raw materials from the soil mechanics viewpoint, - critically evaluate the applicability of laboratory and field research methods in raw materials and soils, - critically evaluate the planning and execution of research in soils, - analyze the results of research in soils, - critically evaluate the factors and processes that affect the quality of the research results in soils, - present the importance of soil investigation in geotechnical and mining practice, - design the research studies, - report the work done through a professionally formed report. -
Course content	***Laboratory and field research methods in soils*** The representativeness of soil samples (disturbed and undisturbed). Engineering properties of soil (drained and undrained shear strength; deformability; hydraulic and gas permeability; soil compaction). Laboratory methods of research in the device for direct shear, oedometer and triaxial shear device. Test conditions (saturated and unsaturated). Field research methods (CPT, SPT, FVT, DMT, PMT). Application of the field research results and their correlation. Field observations of the stress and displacements.
Method of instruction	Lectures / Consultations Independent work in the laboratory and / or in the field Preparation and presentation of a seminar paper
Evaluation of student performance	Validation and presentation of laboratory and / or field research results; evaluation of the writing and presentation of a seminar paper; oral examination.

20-R07-2 Course description	
Name of the course	***Laboratory and field research methods in mining and geotechnics – Unit 2: Laboratory and field research methods of rock material (5 ECTS)*** ***- teacher: Briševac, Z.***
Goals of the course	- connect the various features of raw materials with appropriate laboratory and field tests conducted in rock mechanics and other investigations of rock materials, - demonstrate the planning and execution of research, - present the interpretation, analysis, and application of research, - present the role of research during various stages of design and execution of mining and construction works, - present the importance of various factors and processes that can effect on the quality of research results
Expected learning outcomes (levels 8.2)	- analyze the laboratory and field research methods of raw materials from the rock mechanics viewpoint, - critically evaluate the applicability of some laboratory and field research methods in raw materials, - critically evaluate factors and processes that influence of the quality of research results in rock material, - critically evaluate the ways of interpretation and application of research results, - present the importance of research in raw materials during the various stages of design and execution of mining works and the importance of research in rock geotechnical works and construction of facilities, - analyze methods and possibilities of estimating for the physical and mechanical properties of rock material, - critically evaluate the results of the estimates of important physical and mechanical properties of rock material.
Course content	**Laboratory and field research methods of rock material:** Laboratory method for determining the strength and deformability, index properties and dynamic properties of rock material. Field methods of determining the stress and deformability.
Method of instruction	Lectures / consultations Independent study of the literature, work in the laboratory and/or in the field Preparation and presentation of a seminar paper
Evaluation of student performance	Validation and presentation of laboratory and / or field research results; evaluation of writing and presenting a seminar work; oral exam.

20-R08-1 Course description	
Name of the course	***Mine safety and explosion protection– Unit 1: Explosion protection (3 ECTS)*** ***Teacher: Kuhinek, D.***
Goals of the course	- Present flammable substances properties and classification - Define primary and secondary explosion protection - Demonstrate classification of hazardous area endangered with explosive atmosphere - Present electric and nonelectric ignition sources - Present secondary explosion protection various types
Expected learning outcomes (levels 8.2)	1. Design an implementation of primary explosion protection 2. Combine flammable substances properties with appropriate devices that can be used in processes where explosive atmosphere occur 3. Design hazardous area classification (determination of hazardous zones and extent of occurrence) 4. Design a risk assessment
Course content	**Explosion protection:** Properties of flammable and explosive mixtures of gas, liquid vapors, dust, mist, fibers – density, explosive limits, energy and temperature of ignition. Classification of emission sources. Requirements for primary explosion protection and protection systems. Classification of areas endangered by explosive atmospheres and determination of hazard zones. Electrical and nonelectrical ignition sources. Physical characteristics of explosions – heat released by the explosion, temperature, pressure, brisance, explosion transmission. Principles of secondary protection for electrical and nonelectrical devices. Implementation of explosion protection: G+D, d, t, p, pD, fr, i, b, m, q, o, e, c. Marking of explosion-protected apparatus. Equipment and facility risk assessment, ATEX 95 and 137, certification, evaluation of qualification.
Method of instruction	Lectures Exercises Seminar paper (student project)
Evaluation of student performance	Student project: Designing the hazardous area classification endangered with explosive atmospheres with different solutions that comply with explosion protection principles. Comparison of technical and economical indicators of explosion protection different solutions. Oral exam.

20-R08-2 Course description	
Name of the course	***Mine safety and explosion protection – Unit 2: Mine safety (6 ECTS)*** ***Teacher: Klanfar, M.***
Goals of the course	- Demonstrate the features of the working environment and it's interaction with potential dangers in mining operations - Define the specifics of mining operations and highlight experiences in the occupational safety of workers - Define occupational diseases and injuries, and the methodology of related data analysis - Analyze dominant hazards to human health in mining operations and highlight methods of monitoring adverse events and appropriate protection measures - Define the means of hazard prevention and gaining a certain quality of the working environment - Analyze microclimate factors and define measures to achieve optimal conditions for human health in working environment
Expected learning outcomes (levels 8.2)	5. Describe the working environment with respect to potential danger and hazards in mining environment 6. Propose methodology of monitoring the safety and health of employees in the work area and mining environment 7. Propose analytical or numerical methods for estimating the potential risks to the health and lives of people in the working environment 8. Establish methodologically a relation between empirical data about hazards that endangered the health and lives in mining environment 9. Generate models of prevention and gaining optimum quality of working environment with respect to safety and health
Course content	**Mine safety:** The legal framework of occupational safety in mining environment. Specifics of mining operations, a critical review of mining practices and directions to improve the safety of workers. Ergonomical and safety aspects of mining production. Injuries and occupational diseases. Selected topics of dominant hazards in mining operations (explosions, fires, fumes, dust, noise, vibration, etc.) and the appropriate safety measures. The impact of mining operations on the safety of people in and around the mining area. Methods for monitoring adverse events in and around the mining environment. Scientific and technical analysis and assessment of possible hazards the mining area. Modeling of dangerous incidents and hazards in mines. Modelling of mining disasters. Preventive actions and monitoring the quality of workplace and the surrounding environment. Microclimate factors and means of conditioning the mining working environment. Modeling techniques to improve the security and health conditions in and around the mine. The human and economic aspects of occupational safety in the mining industry.
Method of instruction	Lectures Exercises Seminar paper (student project)
Evaluation of student performance	Student project: Designing the conceptual and mathematical model of hazardous events dangerous to human life and health, and proposition of safety measures. Evaluation of exercises, presentation of seminar paper and oral exam.

20-R09 Course description	
Name of the course	***Modelling and simulation in primary and secondary raw material processing (8 ECTS)*** ***- teacher: Bedeković, G.***
Main goals	- present characteristics of particle populations and distribution functions, - present of mineral/material liberation distribution, - present the influence of the physical and mechanical properties, grain size distribution and mineral/material liberation on mineral processing and recyclability, - present technological parameters of primary and secondary material processing efficiency, - elaborate classification parameters and models in gravity and centrifugal field of forces, - elaborate concentration methods (gravity and magnetic concentration, froth flotation) and solid-liquid separation, - elaborate simulation of unit processes in primary and secondary material processing, - present typical recycling flowsheet of certain waste material type, - present the economic aspects of material processing.
Expected learning outcomes (level 8.2)	- formulate characteristics of particle population and function distributions (1 ECTS), - distinguish different cases of material liberation and based on that recommend appropriate concentration method (1 ECTS), - to design different variants of primary and secondary material processing flowsheets and based on their simulations to recommend the optimal one (1 ECTS), - evaluate effectiveness of the primary and secondary material processing (1 ECTS), - choose appropriate separation methods for waste recycling according to the waste characteristics (1 ECTS), - design a technological process of the primary and secondary materials processing (2 ECTS), - evaluate the economic benefits of materials processing (1 ECTS).
Outlines /module content	Particle population and distribution functions. Minerals/materials liberation and its simulation. Influence of physico-mechanical properties, grain size distribution and mixtured material components on material processing. Technical indicators of material processing efficiency. Classification in gravity and centrifugal field. Sieving models. Critical size grains and grain passing probability. Comminution theory. Bond work index. Energy aspects of comminution and comminution models. Optimization of the crushing and milling processes. Gravity concentration. Determination of material separability by gravity concentration. Magnetic concentration. Behavior of particles in magnetic fields. Magnetic properties of materials. Theory of froth flotation. Reaction processes on a mineral surface. Air bubble mineralization. Froth flotation kinetics. Solid-liquid separation. Simulation of continuous thickener operation. Models for the sedimentation velocity. Simulation of mineral processing plants. Principles of processes used in solid waste recycling: hand picking, sieving, classification in fluids, comminution, optical sorting, air separation, gravity separation, magnetic separation, froth flotation, electrostatic separation, eddy-current separation. Recycling of municipal waste, polymers, metals, glass packaging, e-waste, construction waste and mining waste. Influence of product constructional properties on recyclability. Economy related aspects of recycling.
Method of instruction	Lectures (ppt presentation) (1,5 ECTS), laboratory exercises (2 ECTS), computer exercises (2,5 ECTS) and student seminar paper (2 ECTS).
Evaluation of student	1. Students seminar paper.

performance	2. Oral exam 3. Student project: Development of material processing flowsheet simulation.

20-R10-1 Course description	
Name of the course	***Environmental management – Unit 1: Environmental Geotechnics (4 ECTS) - teacher: Kovačević Zelić, B.***
Goals of the course	– present the impact of geotechnical structures and anthropogenic activities on the environment, – present the influence of natural hazards on geotechnical structures, – define site exploration program for the problem characterization, – define analytical and numerical methods for geotechnical calculations, – present the intelligent use of geotechnical knowledge and activities intended to minimize negative impacts on structures and nature
Expected learning outcomes (levels 8.2)	– define natural hazards and anthropogenic activities which can cause negative impacts on the environment and geotechnical structures, – foresee likely negative impacts and control their consequences, – combine different research methods for problem characterization, – apply analytical and numerical methods for geotechnical calculations intended for the solution of environmental problems, – design geotechnical protection and remediation measures, – plan activities and monitoring programs for geotechnical structures used for environmental protection
Course content	**Environmental Geotechnics:** Natural and man-made hazards and risks. intelligent use of geotechnical knowledge and activities intended to prevent or minimize negative impacts on structures and nature. Negative impacts on environment, control of consequences and application of protective measures related to geotechnical works. Landfill design for municipal, hazardous, and nuclear waste. Laboratory and in-situ characterization. Geotechnical principles applied to the landfill design. Methodology and criteria for landfill site selection. Landfill closure and monitoring. Traditional and innovative construction materials. Compatibility and long-term performance of mineral barriers. Mineral waste from raw materials extraction. Remediation of contaminated sites and landfills: geotechnical measures for in-situ soil improvement and pollutant control.
Method of instruction	Lectures, examples and case studies from scientific journals and reports, supervision in the preparation of student essays involving either numerical calculations or laboratory work.
Evaluation of student performance	Student essay on specific subjects. Oral exam.

20-R10-2 Course description	
Name of the course	***Environmental management – Unit 2: NORM residues and Low and Intermediate Level Radioactive Waste Management and Disposal (4 ECTS)*** ***- teacher: Veinović, Ž.***
Goals of the course	− Define the methodology for management of NORM residues, − Assess the impact of NORM residues on biota, − The application of methods of remediation of sites with NORM residues depending on the material, the amount of material and the geometry of the disposal site, − Define technology for LILW characterization and storage, − Assess different type of storage facilities and containers, − Present methodology for disposal of LILW and different concepts of disposal facilities, − Present methodology for implementation of the safety and security systems for LILW repositories, − Define methods of long-term monitoring of the repository.
Expected learning outcomes (levels 8.2)	− design security and safety systems at the NORM residues and LILRW repositories − design numerical models with initial and boundary conditions for specific cases of radionuclide migration − propose analytical or numerical methods of solving mathematical models − suggest design of repositories with optimal parameters
Course content	**NORM residues and Low and Intermediate Level Radioactive Waste Management and Disposal:** NORM residues and LILRW properties and processes of production, alteration and influence of these materials upon the environment and people. Conditioning and pre-treatment of NORM residues and LILRW. Design and characteristics of near surface and shallow repositories of NORM residues and LILRW. Selection, design optimization and modelling of the evolution of the composition of materials to produce engineering barriers. Modelling the change of engineering barrier materials with time and transport of radionuclides through engineering barriers and geological environment.
Method of instruction	Lectures, application of specialized software through analysis of examples from practice and case studies from scientific journals.
Evaluation of student performance	Student's essays on specific subjects. Oral exam.

20-R10-3 Course description	
Name of the course	***Environmental management – Unit 3: Air Quality Management (4 ECTS)*** ***- teacher: Sobota, I.***
Goals of the course	− define problems relating air pollution and protection − present the air protection regulations − present the methods of air quality and emissions monitoring − present the technology and devices for air and flue gas cleaning in mining industrial and waste treatment processes
Expected learning outcomes (levels 8.2)	− explain basic terms and principles relating air pollution and protection, and identify relevant Croatian and EU air protection regulations − classify the sources of air pollution and explain the characteristics of individual pollutants − analyze (assess) the main impacts of air emissions and propose principal protection measures for individual impacts − plan air quality and emissions monitoring − analyze the application possibilities of air/gas cleaning methods and equipment used in mining, industrial and waste treatment processes, with regard to the characteristics of treated fluid and method itself − propose appropriate air/gas cleaning methods and equipment
Course content	**Air Quality Management:** Atmospheric structure and composition. Emission and imission (definitions and expressions). Air pollution sources and types of air pollutants. Effects of air pollution on the environment and people. Overview of strategies and measures for air emission control and air quality improvement. Methods of air quality and emissions monitoring: sampling, measurement and modelling methods, data analysis and interpretation with regard to emission limit values and air quality limit values. Meteorological parameters of air pollution transport. Atmospheric dispersion modelling. Determination of occupational exposure to inhalable and respirable dust. Measurement of gas emissions (gas analyzers). Dynamics of particles. Classification of air/gas cleaning equipment. Application, features, operational principles, dimensioning and efficiency determination of individual control devices: gravity settlers, momentum separators, aerocyclones, fabric (bag) filters, electrostatic precipitators, wet and dry scrubbers. Environmental Pollution Register (emission inventory). Air protection standards and legislation.
Method of instruction	Lectures and consultations, writing a seminar paper and demonstration relating air quality and emissions monitoring.
Evaluation of student performance	Student essay on specific subjects. Oral exam.

20-R11-1 Course description	
Name of the course	***Modelling of geological materials – Unit1: Continuum mechanics (3 ECTS)*** ***- teacher: Jaguljnjak Lazarević, A.***
Goals of the course	- formulate numerical models for solving technical problems, - analyze approximation of a numerical model, - application of mathematical physics in solving boundary value problems in continuum mechanics
Expected learning outcomes (levels 8.2)	- apply tenzor analysis to examples in technical mechanic - formulate fundamental concepts and principles in continuum mechanics of solids: geometry of motion, equilibrium equations, constitutive relations and boudary conditions - define the effect of discontinuity in solid mechanics - analyze solution strategies
Course content	Concepts and principles in continuum mechanics of solids and possibility of its application in solving engineering problems in soil and rock mechanics.
Method of instruction	Lectures or Consultations and demonstration computer exercise, writing a seminar. Teaching material encompasses textbooks from Croatian and foreign universities and the computer program Wolfram Mathematica.
Evaluation of student performance	Evaluation of writing and presenting a seminar work about fundamental principles of continuum mechanics.

20-R11-2 Course description	
Name of the course	***Modelling of geological materials – Unit 2: Modelling in soil mechanics (4 ECTS) - teacher: Kovačević Zelić, B.***
Goals of the course	- formulate numerical models for solving geotechnical problems, - present constitutive laws in soil mechanics, - present the concept of critical state soil mechanics and critical state model, - define the advantages and limitations of numerical modelling, - evaluate and critically examine the results of numerical calculations
Expected learning outcomes (levels 8.2)	- select appropriate constitutive law and method for the numerical calculations for the solution of geotechnical problems in soil mechanics, - hypothesize the occurrence of the critical state, - generate numerical model with initial and boundary conditions for specific geotechnical structures, - perform numerical model optimization and evaluation of numerical calculations results by taking into account real conditions.
Course content	Constitutive modelling in soil mechanics. Continuum mechanics, elasticity and plasticity theories applied to soils. Critical state soil mechanics. Duncan-Chang and Cam-clay model. Numerical programs and computer codes in soil mechanics. Advantages and limitations of numerical calculations. Selection of input parameters. Applications of limit equilibrium and limit plasticity analysis methods to stability problems in geotechnical engineering, such as slopes, cuts, underground works and retaining structures. Evaluation of numerical calculation results.
Method of instruction	Lectures/supervision for the preparation of the review on a specific geotechnical problem, numerical simulations, and analysis of the results.
Evaluation of student performance	Evaluation of a student's project; oral exam.

20-R11-3 Course description	
Name of the course	***Modelling of geological materials – Unit 3: Modelling in rock mechanics (3 ECTS) - teacher: Hrženjak, P.***
Goals of the course	- define the models and methodology of modelling in rock mechanics, - present constitutive equations for certain models of rock behavior, - present the concepts of continuous, discontinuous, and quasi-continuous geotechnical unit in modelling the behavior of rocks and rock masses, - define the advantages and limitations of numerical modelling, - evaluate and critically examine the results of numerical calculations.
Expected learning outcomes (levels 8.2)	- formulate the problem of modelling task in rock mechanics, - select appropriate conceptual models and calculation methods, - set up and perform calculations of numeric models, - evaluate and present the results of numerical models, - synthesize the results of different models and calculation methods with the aim of finding optimal solutions.
Course content	Conceptual, mathematical, numerical, and stochastic models and processes of modelling in rock mechanics. Application of analytical, numerical, and statistical calculation methods in modelling processes. Intact rock material, discontinuities of structural domain, the main structures and geometry of model as the main elements of the rock mass model. Modelling state and behavior of rocks and rock masses to the concept of continuous, discontinuous, and quasi-continuous geotechnical domain for various engineering works in them. Formulating the problem of modelling tasks in rock mechanics and selecting the appropriate models and calculation methods. Application of different computer programs in modelling the state and behavior of rocks in different conditions of mining and geotechnical structures in rocks. Collection, processing, and selection of input data required for numerical modelling. Methods of model validation and evaluation of modelling results. The synthesis of different model results and calculation methods in finding optimal solutions for the set tasks.
Method of instruction	Lectures / consultations / demonstrations. Preparation of the project assignment.
Evaluation of student performance	Evaluation of a student's project through evaluation of model setting, input data selection, numerical calculation, validation, and presentation of results; oral exam.

20-G01-1 Course description	
Course title	***Basin analysis – Unit 1: Geochemical exploration of source rocks and reservoir fluids (5 ECTS)*** ***- teachers: Velić, J.; Saftić, B.***
Course aims	Velić, J., prof. emerita: - Define methods for evaluating petroleum-bearing rocks based on geochemical studies and how the results can contribute to the reconstruction of petroleum geological systems. - Present and explain models of oil generation in the Croatian part of the Pannonian Basin, as well as in platform and post-platform sediments in the Dinarides and the Adriatic Sea basin. Saftić, B., assoc. prof.: - Demonstrate how teamwork among various specialists (geologists, geochemists, geophysicists) leads to the discovery of new hydrocarbon deposits. - Explain the impact of sequence stratigraphic analysis on the exploration potential of rock composition and structure within basins. - Illustrate how boundaries of petroleum geological systems can be determined and genetically classified.
Expected learning outcomes (level 8.2)	- describe the structure of different basin types and understand the conditions and mechanisms of the accumulation of organic matter within them - plan and manage the studies of petroleum source rocks and reservoir fluids - interpret the results of geochemical analyses of source rocks to estimate their generative potential and maturity level - interpret the results of geochemical analyses of reservoir fluids to estimate their composition in reservoirs and their correlation with mature source rocks - synthesize the results of geochemical exploration and integrate them in reconstruction of hydrocarbon leads and plays.
Course content	**Geochemical exploration of source rocks and reservoir fluids** Sedimentary basins and global tectonics. Basin types – extensional, flexure, strike-slip, foreland, fore-arc and back-arc basins. Basin fill – source of sediments and depositional environment. Sequence stratigraphy and stratigraphic correlation. Integrated interpretation of geological, geophysical and geochemical exploration results. Geochemical prospecting and different rock and fluid tests. Rock and fluid sampling methods during fieldwork (outcrops) or in the wells. Characterisation of source rocks. Correlation and comparison with geological and geophysical (e-logs) data. Reconstruction of source rock genesis and their position in the regional geological evolution. Estimation of the regional petroleum potential/prospectivity. Evaluation of palaeotemperature, geothermal gradient and time of expulsion and migration. Estimation of generated volumes regarding type and distribution of rocks and generation processes. Correlation between the source rocks and oil (gas) or between the oil and oil (gas and gas). Migration history and pathways. Geochemical processes in preservation or degradation of a reservoir. Regional evaluation of a petroleum basin based on hydrocarbon geochemistry investigations. Croatian examples. Exercises: fieldwork (geochemical prospecting), sampling and demonstration in laboratories, computer modelling (1D basin modelling).
Method of instruction	*Lectures, fieldwork – prospection and sampling of source rocks, laboratory work, individual work on seminars.*
Evaluation of student	*Active participation of students is required, including attendance to lectures and*

performance	*consultation meetings, writing of term papers (seminars) and preparing presentations. The most important part of the student's grade refers to the quality of seminars and competence for individual work. The exam consists of written and oral part with attention to written and oral expression.*

20-G01-2 Course description	
Course title	***Basin analysis – Unit 2: Basin modelling and regional petroleum potential assessment (5 ECTS)*** ***- teachers: Kolenković Močilac, I.; Cvetković, M.***
Course aims	**Cvetković, M.:** - Explain the formation of different types of basins with regard to the global tectonics and describe what types of basins can develop in different geological settings, - Analyze structural, sedimentological, and geochemical elements of petroleum geological systems to interpret and understand their characteristics. - Analyze research results to assess the economic viability of potential hydrocarbon deposits. **Kolenković Močilac, I.:** - Identify key parameters and indicators enabling the identification of petroleum geological systems within geological basins. - Identify and assess risks and challenges associated with the exploration and exploitation of specific deposits. - Communicate research findings through clear, structured, and detailed reports.
Expected learning outcomes (level 8.2)	- describe regional geological setting in terms of the probability of generation and accumulation of hydrocarbons - interpret the petroleum systems within a basin through the definition of their elements - make conclusions on the probability of hydrocarbon discovery in the regional scale studies - estimate the results and economic effects of exploration, analyse the risk of orientation on certain exploration targets - manage the petroleum-geological exploration by applying interdisciplinary approach in solving problems - prepare the comprehensive report on the results of petroleum-geological exploration on a regional scale.
Course content	**Basin modelling and regional petroleum potential assessment** Application of the basin analysis to petroleum exploration – hypothesis and identification of petroleum systems and their genetic classification. Elements of a petroleum system – mature source rocks, migration paths, reservoir rocks, cap rocks and traps. Delimiting petroleum systems – stratigraphic span, (palaeo-)geography, age of activity. Genetic classification of petroleum systems – quality and volume of source rock formations, migration types, trapping efficiency. Economic factors for planning of petroleum exploration in basins that are at different stage of exploration. How the definition of the petroleum system elements influences the risk of exploration at the regional scale (definition of a play) or at the local scale (definition of a prospect). Exercises: independent work – 2D and 3D basin modelling, analysis of the two petroleum basins from the literature and writing the two review texts in form of exploration reports.
Method of instruction	*Lectures, exercises in computer modelling, individual work on seminars.*
Evaluation of student performance	*Active participation of students is required, including attendance to lectures and consultation meetings, work on the computer, writing of term papers (seminars) and preparing presentations. The most important part of the student's grade refers to the quality of seminars and competence for individual work. The exam consists of written and oral part with attention to written and oral expression and the skills of using information technologies/various computer software developed for modelling in hydrocarbon geochemistry and petroleum geology.*

20-G02-1 Course description	
Course title	***Geological modelling of oil and gas reservoirs – Unit 1: Exploration methods of reservoir and cap rocks' structure and characteristics (5 ECTS)*** ***- teachers: Velić, J.; Kolenković Močilac, I.***
Course aims	**Velić, J., prof. emerita**: - To explain formation of structural and stratigraphic traps in different regional or local geological settings - To present interpretation of results of various geophysical exploration methods aimed towards the definition of the reservoir boundaries in the subsurface - To present the data acquisition techniques used for reservoir and cap rocks' characterization (direct and indirect methods) - To classify reservoirs with respect to reservoir fluid **Kolenković Močilac, I., assist. prof.:** - Conduct an analysis of clay volume based on electric log analysis. - Perform a simple estimation of porosity using one or two "porosity log" curves (acoustic logging, neutron logging, and/or density logging). - Specify and explain laboratory measurements used for estimating the sealing properties of rocks.
Expected learning outcomes (level 8.2)	1. Describe structure of different trap types and understand mechanisms of their formation 2. Analyze composition and structure of reservoir and cap rocks and define their spatial relations 3. Characterize a reservoir based on analyses of core samples and reservoir fluids, integrated with results from well log interpretation 4. Synthesize the results of geological, geophysical and geochemical exploration of a reservoir to prepare the data for construction of geological model
Course content	**Exploration methods of reservoir and cap rocks' structure and characteristics** Structural traps and mechanisms of their formation. Classification of stratigraphic traps based on the time of their formation (primary and secondary traps) and based on the type of the reservoir rock (clastic, carbonate, metamorphic and magmatic rocks). Correlation of well data. Methods of seismic surveys interpretation (2D and 3D data). Conversion of data from time scale to depth scale. Methods of petrophysical characterization of reservoir rocks and cap-rocks (direct and indirect). Methods used to determine the saturation and composition of reservoir fluids by means of laboratory measurements and well log interpretation. Interpretation of results of petrophysical measurements and reservoir fluid analyses. Data preparation and management techniques for geological modelling of a reservoir. Exercises: working on procedures of data preparation and practices of data management for geological modelling (integrating the core analyses with the results of interpretation of different geophysical measurements).
Method of instruction	*Lectures, exercises in data preparation for computer modelling, individual work on seminars*
Evaluation of student performance	*Active participation of students is required, including attendance to lectures and consultation meetings, work on the computer, writing of term papers (seminars) and preparing presentations. The most important part of the student's grade refers to the quality of seminars and the independent work in sense of independent preparation of interpretations which are input data for modeling.*

20-G02-2 Course description	
Course title	***Geological modelling of oil and gas reservoirs – Unit 2: Construction of geological model and continuation of research in the phase of reservoir development and production (5 ECTS)*** ***- teachers: Saftić, B.; Cvetković, M.***
Course aims	- Saftić, B. - To present interpretation of results of various geophysical exploration methods aimed towards the definition of the reservoir boundaries in the subsurface - To define ways of making well to seismic ties – establish the relation between the depth and time scale - To explain how to prepare a report on exploration results – a study within the area of one oil or gas field - Cvetković, M - To present basic reservoir modelling techniques (simple models and models that include several hydrodynamic units) - To present the basics of lithofacies and petrophysical modeling of hydrocarbon accumulations - To demonstrate the possibility to use detailed geological models of the subsurface for targeted exploration of reservoirs within certain field or in its vicinity (satellite reservoirs)
Expected learning outcomes (level 8.2)	1. Construct the geological model of a reservoir and estimate the geological reserves of oil and gas 2. Upscale the geological model for purpose of dynamic modelling 3. Manage geological research during the phase of reservoir development and production with the aim of recovery increase 4. Make plans and manage exploration for additional reserves in satellite reservoirs within an exploitation field Prepare the comprehensive report on results of petroleum-geological exploration of one hydrocarbon field
Course content	**Construction of geological model and continuation of research in the phase of reservoir development and production** Methods of model development – simple and complex models (several hydrodynamic units). Influence of faults on the spatial distribution of fluids. Relationship between lithofacies mapping and modelling. Methods to define spatial relations between lithofacies units in the reservoir. Basics of petrophysical mapping and modelling (data preparation, algorithms). Procedures for estimating geological reserves of hydrocarbons. Procedures for model up-scaling as adjustment needed for dynamic modelling. Application of modelling results for directing exploration with the aim of discovering additional reserves or reservoirs within an oil or gas field. Presentation in how to prepare a report on geological exploration of a field. Exercises: individual work on development of a geological model of a reservoir and writing of a report on the results of petroleum-geological exploration.
Method of instruction	*Lectures, exercises in computer modelling, individual work on seminars.*
Evaluation of student performance	*Active participation of students is required, including attendance to lectures and consultation meetings, work on the computer, writing of term papers (seminars) and preparing presentations. The most important part of the student's grade refers to the quality of seminars and model development. The exam consists of written and oral part with attention to written and oral expression and the skills of using information technologies/various computer software developed for the petroleum geological exploration to define and map the geological structure and composition in the subsurface.*

20-G03-1 Course description	
Course title	***Regional geology and tectonics – Unit 1: Stratigraphy of Neogene basins in Croatia (5 ECTS)*** ***- teacher: Pavelić, D.***
Course aims	- to present stratigraphic units and existing depositional models of Neogene basins in Croatia, - to define and explain about methods and analytical procedures in stratigraphic research of Neogene basins in Croatia, - to present still ambiguous and unsolved questions on dating of Neogene strata and events
Expected learning outcomes (level 8.2)	1. Describe stratigraphic units of Neogene basins in Croatia 2. Determine systems of stratigraphic classification 3. Plan adequate methods and analytical procedures in stratigraphic research of Neogene basins in Croatia with respect to the present-day exploration level and knowledge 4. Construct depositional models for selected parts of Neogene basins in Croatia 5. Synthesize available and integrate self-obtained results of stratigraphic and sedimentological explorations aimed at interpretation of depositional history of Neogene basins in Croatia
Course content	**Stratigraphy of Neogene basins in Croatia** Dating methods. Central Paratethys. Neogene time scale. Hrvatsko Zagorje basin. North Croatian Basin. Problem of chronostratigraphic dating. Opening of the sedimentary basin. Lithological types. Sedimentary environments. Sedimentary successions. Tectonic controls. Causes of establishment and closing of the connection to the sea. Synrift/postrift boundary. Reasons of cyclicity. Endemism of fauna. Nature of volcanism. Causes of erosion. Regional and local unconformities. Closening of the basin. Freshwater basins within the Dinarides. Lithological types. Sedimentary environments. Critical stratigraphic problems. Radiometric dating. Magnetostratigraphic dating. Adriatic basin. Marine and terrestrial deposition. Messinian salinity crisis. Pliocene transgression. Pleistocene glaciation and glacio-eustatic sea level changes.
Method of instruction	*Lectures, exercises, individual work on seminars*
Evaluation of student performance	*Evaluation of individual work on exercises, on seminars and oral exam.*

20-G03-2 Course description	
Course title	***Evolution of the Adriatic Carbonate Platform (5 ECTS)*** ***- teacher: Vlahović, I.***
Course aims	– to present stratigraphic units of the Adriatic Carbonate Platform and critically evaluate concepts of its architecture and evolution, – to define elements necessary for subdivision of the External Dinarides and Istria stratigraphic units into depositional units of higher order, – to present palaeogeographical, depositional and tectonic factors which interacted to result in the present-day architecture of the External Dinarides and Istria.
Expected learning outcomes (level 8.2)	1. Describe and critically evaluate concepts of the architecture and evolution of the Adriatic Carbonate Platform and its underlying and overlying deposits; 2. Describe stratigraphic units of the Adriatic Carbonate Platform and its underlying and overlying deposits; 3. Describe differences between carbonate platform as a sedimentologically defined depositional body, separate palaeogeographic entity and structural-tectonic element; 4. Design and elaborate basic elements of the procedures for investigation of carbonate depositional systems of the Adriatic Carbonate Platform and its underlying and overlying deposits in accordance with defined elements; 5. Synthesize the existing results and integrate their own research results into an existing or new depositional model of the Adriatic Carbonate Platform.
Course content	**Evolution of the Adriatic Carbonate Platform** Overview of the present geotectonical and palaeogeographic concepts of the External (Karst) Dinarides and Istria – similarities and differences. Composition of the External (Karst) Dinarides and Istria – relationship between palaeogeographic, structural-tectonic and geomorphologic elements. Palaeogeographic relationships in the Perrimediterranean area during the late Palaeozoic, Mesozoic and Cenozoic. Concepts on the existence of one or two carbonate platforms during the Mesozoic and early Cenozoic. Terminological differences between different names of the carbonate platform within the External Dinarides and Istria and different opinions on the stratigraphic range of the platform. Deposits underlying the Adriatic Carbonate Platform: (1) epeiric carbonate platform along the Gondwana margin (until Middle Triassic) and (2) more or less isolated huge carbonate platform (from Middle Triassic to the end of Early Jurassic) – palaeogeography, architecture, main events. Adriatic Carbonate Platform from the end of the Early Jurassic to the end of Cretaceous – palaeogeographic relationships, general architecture and succession of platform deposits, main eustatic and synsedimentary tectonic events and their consequences on the evolution of the platform (emergences, drownings, oceanic anoxic events), importance of fossils for palaeobiogeographic considerations, production of shallow-marine carbonates and correlation with neighbouring areas, disintegration of the platform in the Late Cretaceous. Problem of the temporal definition of the Adriatic Carbonate Platform as separate palaeogeographical entity. Deposits overlying the Adriatic Carbonate Platform – succession of Palaeogene deposits and subsequent geological events. Utilization of modern analytical methods in the study of the Karst Dinarides: palaeomagnetism, stable isotopes, geochemical analysis, geothermochronological methods, etc.
Method of instruction	*Lectures, individual work on seminars*
Evaluation of student performance	*Evaluation of individual work on seminars and oral exam.*

20-G03-3 Course description	
Course title	***Regional geology and tectonics – Unit 3: Tectonics (5 ECTS)*** ***- teacher: Tomljenović, B.***
Course aims	- to present historical development of the theory of Plate Tectonics and to explain about structural styles and tectonics at divergent, transform and convergent plate boundaries (extensional, strike-slip and compressional tectonics), - to explain about structural styles and tectonics in regions affected by salt tectonics, - to present the classification and description of main tectonics units of the Alpine–Dinarides–Carpathian orogenic system
Expected learning outcomes (level 8.2)	1. Outline the milestones in development of the theory of Plate tectonics 2. Elaborate about structural styles and tectonics at divergent, transform and convergent plate boundaries, at passive continental margins, in intra-continental rifts, in back-arc and in foreland basins 3. Elaborate about structural styles and tectonics in regions affected by salt tectoncs 4. Elaborate about structural-geological characteristics of major tectonic and tectono-stratigraphic units of the Dinarides, in Adriatic and Pannonian basins in Croatia and to interpret the tectonic history of the Alpine–Dinarides–Carpathian orogenic system Synthesize available and integrate self-obtained results of structural-geological explorations aimed at improvement of existing and construction of new models on tectonic history of the Dinarides, Adriatic and Pannonian basins in Croatia
Course content	**Tectonics** Plate tectonics: chronology of development. Divergent plate boundaries and extensional tectonics: structural styles and tectonics at active mid-ocean ridges, in continental rifts and in extensional basins. Tectonic models of extensional fault systems from rifting to spreading and formation of passive continental margins. Transform plate boundaries and strike-slip tectonics: origin and types of transform faults, kinematics of regionally important transcurrent faults (San Andreas fault, Dead Sea f. and Periadriatic f.). Tectonic models in formation of pull-apart basins. Convergent plate boundaries and compressional tectonics: structural styles and tectonics in subduction and collision zones, in fold-thrust belts and in regions affected by escape tectonics. Salt tectonics: rheological properties of salt, major forms of salt bodies, expression of salt in reflection seismics, extensional and compressional salt tectonics. Tectonic units of the Alpine–Dinarides–Carpathian orogenic system: classification, structural styles and tectonic evolution. Exercises: Structural interpretation of selected reflection seismic sections, construction of profiles in regions affected by extensional, compressional and strike-slip tectonics. Presentation of seminars: 20 min. student presentation on selected topics.
Method of instruction	*Lectures (3 ECTS), exercises, individual work on seminars*
Evaluation of student performance	*Evaluation of individual work on exercises, on seminars and oral exam.*

20-G04 Course description	
Name of the course	***Quaternary geology (5 ECTS)*** ***- teachers: Velić, J.; Cvetković, M.***
Goals of the course	- present the historical development of the chronostratigraphic and geochronological subdivision of Quaternary according to internationally approved standards - explain surface and subsurface exploration methods used for Quaternary sediments studies - define the interpretation methods that are applicable for geological data of Quaternary age rock formations, including statistical/geomathematical methods. - present the importance and economic value of Quaternary deposits in general and with respect to their specific geological settings in Republic of Croatia - present the significance of Quaternary deposits as regional aquifers - sources of drinking water, together with their significance use in Engineering geology - present the current state of the exploration of Quaternary deposits in the Republic of Croatia
Expected learning outcomes (level 8.2)	**Learning outcomes 1: Quaternary geology (5 ECTS) - J. Velić and M. Cvetković** - understand and compare different stratigraphic definitions of Quaternary (chronostratigraphic, lithostratigraphic, magnetostratigraphic and biostratigraphic) (0,5 ECTS) - comprehend the possibility of the application of different exploration procedures with respect to the specifics of the Quaternary sediments in different geological settings (0,5 ECTS) - classify the mineral resources of Quaternary age in Croatia and learn how to evaluate them with regard to the recent economic situation in the Republic of Croatia (2 ECTS) - understand the influence of climate change on the morphological characteristics of the terrain (0,5 ECTS) - plan exploration of Quaternary age sediments (1,5 ECTS)
Course content	**Lectures:** Stratigraphy of Quaternary and different systems of stratigraphic units. Evaluation and review of the existing systems of stratigraphic units for the period (geochronologic) or system (chronostratigraphic) of the Quaternary. Milankovic's Cycles. Methods used for exploration of Quaternary sediments, different surface and subsurface exploration methods (geomorphological features, outcrop investigations, sampling methods, sample quantities and spatial distribution, laboratory analyses, drilling, geophysical methods, sample preparation for laboratory analyses, statistical/geomathematical analyses). Age determination methods. Presentation of results: graphical, statistical, etc. The basics of Quaternary palaeontology with special regard to palaeontology of mammals and palynology. Glacial, proglacial and periglacial forms. Influence of glaciation and interglacial changes on relief and plant and animal life. Quaternary rocks in Croatia (marine, lake, brackish and freshwater, wetland, river, terrestric, glacial and periglacial) and their significance from aspect of engineering geology and hydrogeology. Latest results of the investigations of glacial erosion and accumulation of glaciers in the Mt. Velebit and Mt. Biokovo areas. Quaternary mineral resources in Croatia with special regard to gas deposits in the Northern Adriatic and mineral raw materials used in construction. **Exercises:** **Field work:** recognition of Quaternary sediments, identification of facies in respect to superposition, lithologic composition fossil content etc., sampling exercise in terms of quantity and density of sampling points, statistical/geomathematical data processing, modelling.

	Individual work: Presentation of independent research based on chosen topic and areas of exploration or writing a seminar paper on possible new exploration of Quaternary age deposits.
Method of instruction	Lectures (1,5 ECTS), field work or computer modelling (2 ECTS), individual work on seminars or presentation on the selected topic (1,5 ECTS).
Evaluation of student performance	Active participation of students is required, including involvement in creating new content in the form of seminar papers and appropriate presentations. Ability for performing independent field work / research. Oral exam with the attention of oral expression and application of information technology/various software adequate applicable to study of Quaternary sediments.

20-G05-1 Course description	
Name of the course	***Quaternary geodynamics – Unit 1: Structural Geomorphology (4 ECTS)*** ***- teacher: Matoš, B.***
Goals of the course	- Definition of intrinsic and extrinsic variables that influence landscape evolution – explanation of typical holotypes of landscapes - Description of common geomorphic markers that are used in identification of recent tectonic activity - Definition of research and methodological approach that are used in landscape analyses in order to identify landforms associated to ongoing tectonics - Presentation of GIS interface and its usage in methodology definition of quantitative analysis and delineation of morphometric parameters - Explanation of methodological approach in identification of the recent, tectonically active areas and seismogenic faults that combine structural-geological, geomorphic and geophysical dataset - Definition of methodical approach in analysis of recent stress field in the Earth's crust
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able to: 1. Identify and explain structural and geomorphic features of certain areas with respect to proposed models in geomorphic evolution of landscape 2. Recognize and explain intrinsic and extrinsic variables that influence landscape evolution 3. Propose adequate geomorphic markers (terestric and marine), with respect to type of landscape, that should be used in the analysis and assessment of recent tectonic movements 4. Demonstrate skills and knowledge in conducting independent GIS research, i.e., quantitative morphometric analysis of landscape and assessment of its correlation (of computed morphometric parameters) to potential recent tectonic activity 5. Design individual research methodology of geomorphic processes in ceartan area in respect to the research objectives.
Course content	**Tectonic Geomorphology** Lectures: Geomorphic cycle and geomorphic models in landscape evolution: Existing geomorphic models in landscape evolution and definition of intrinsic and extrinsic variables that influence landscape and landform evolution. Isostatic vs. tectonic uplift – landscape. Equilibrium of drainage network – feedback mechanism and dynamic/static equilibrium. Geomorphic markers: Definition of geomorphic markers and its usage in identification and quantification of tectonic activity. Remote Sensing in Tectonic Geomorphology. GIS and its application in Geology and Tectonic Geomorphology: GIS systems, its structure and input data. Geomorphic markers and DEM-based quantitative morphometric analysis. Fault scarps – morphology, diffusion processes and associated sediments. Introduction to seismology and construction of focal mechanism solutions. Analysis of historical earthquake records: Introduction to paleoseismology. Absolute dating techniques and its application in identification of recent tectonic activity. Exercises: Analysis and description of landscape geomorphic features based on satellite images/aerophotos. Computation of tectonic movement rates using geomorphic markers. GIS analysis of digital elevation model with delineation of local relief raster and raster of variable slope angle. Computation of hypsometric

	curves and statistical parameters of longitudinal profiles. Construction of focal mechanism solutions based on seismological data. Individual work: Analysis of two scientific publications (articles) with preparation of report. Preparation of ppt presentation on conducted research (chosen topic).
Method of instruction	Course will be organized trough series of lectures/consultations, exercises and individual work that requires preparation of a seminar paper. In the framework of exercises PhD students will perform practical exercise that in general incorporate computation of morphometric parameters using GIS interface. Within the scope of seminar paper PhD student is required to individually study proposed literature and prepare seminar paper. **ECTS points:** Lectures (**1,5 ECTS**), GIS exercises (**1,5 ECTS**), Preparation and presentation of seminar paper on chosen topic (**1 ECTS**).
Evaluation of student performance	Evaluation and grading of PhD candidates is based on: - active participation in lecture discussions with critical thinking about presented subject/topic. - written and presentation quality of prepared seminar paper - results of conducted GIS exercises and prepared report of achieved results with conclusion - oral exam that consider level of PhD candidate knowledge, cause-effect understanding, understanding of feedback mechanisms, as well as critical thinking of applicability of certain morphometric methods in determination of connection between certain landscape/landforms and ongoing tectonics.

20-G05-2 Course description	
Name of the course	***Quaternary geodynamics – Unit 2: Seismotectonics (4 ECTS)*** ***- teachers: Matoš, B.; Herak Ma.***
Goals of the course	- Presentation of seismological features of divergent, transform and convergent tectonic plate boundaries - Explanation of role of rock mechanics in stress and strain distribution within the Earth's crust - Description of critical conditions of brittle-plastic deformation transiton - Definition of methodical approach in analysis of recent stress field in the Earth's crust - Description of seismic wave properties and demonstration of peculiarities of seismic cycle - Presentation of seismogram properties and principles in empirical positioning of earthquake epicenters, earthquake magnitudes and intensities - Description of basic features of focal mechanism solutions and explanation of its construction - Presentation of earthquake sources and earthquake distribution in the area of Croatia - Explanation of basic features of seismic hazard and seismic risk.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able to: 1. Describe and explain structural and tectonic features of tectonic plate boundaries and stress distribution in Earth's crust 2. Explain importance of rock mechanics in formation of stress field and strain type within the rocks 3. Analyze and assess earthquake epicentral distance as well as earthquake magnitude and earthquake intensity based on available seismogram 4. Compare seismic wave properties with geological factors and its relevance in assessment of seismic hazard and risk 5. Compute focal mechanism solutions based on geometric and kinematic features of investigated faults and argument results of seismotectonic studies in context to regional stress field.
Course content	**Seismotectonics** Lectures: Seismology and plate tectonics: Divergent plate boundaries and extension - Mid-ocean ridges, continental rift zones and extensional basins. Transform plate boundaries ad strike-slip tectonics – kinematic features of transform faults. Convergent plate boundaries and compressional tectonics: structural styles and kinematic features of subduction and collision zones. Rock mechanics and rock deformation: Stresses, strain elipse, stress elipsoide, Mohr-Coulomb failure law, faulting theory. Brittle-plastic deformation - boundary conditions that dictate brittle and plastic deformation. Recent stress field: Research methods and interpretation. International seismological databases. Seismic waves: Theory of waves, S and P-waves, Surface waves, Energy of wavefront, Wavefront reflection and transmission. Seismogram and source parameters: Seismometer and seismological network – basic properties. Magnitude and seismic moment, earthquake intensity and total released earthquake energy, earthquake statistics. Focal mechanism solutions (FMS): Fault geometry, first-motion, seismic wave motion, stereographic projection and FMS construction. Seismotectonic properties of Croatia: Regional structural framework, seismogenic zones and epicentral areas in Croatia. Basic seismic hazard and

	seismic risk properties. Excercises: Tectonic plate boundaries - structural interpretation. Structural interpretation of seismic reflection profiles. Construction of seismotectonic profile. Empirical computation of earthquake epicentral distance and assessment of earthquake magnitude and earthquake intensity based on seismogram. Construction of fault mechanism solution and its interpretation with respect to earthquake catalogue. Individual work: Preparation of seminar paper and ppt presentation on conducted research (chosen topic).
Method of instruction	Course will be organized trough series of lectures/consultations, exercises and individual work that requires preparation of a seminar paper. In the framework of exercises PhD students will perform practical exercise that in general structural analysis with interpretation of reflection profiles in order to compute required seismogenic parameters. Within the scope of seminar paper PhD student is required to individually study proposed literature and prepare seminar paper. **ECTS points**: Lectures (**1,5 ECTS**), Auditor exercises (**1 ECTS**), Preparation and presentation of seminar paper on chosen topic (**1,5 ECTS**).
Evaluation of student performance	Evaluation and grading of PhD candidates is based on: - active participation in lecture discussions with critical thinking about presented subject/topic. - results and quality of conducted exercises and written and presentation quality of prepared seminar paper - oral exam that consider level of PhD candidate knowledge, cause-effect understanding, as well as understanding of correlation between recent stress field and paleostress field. Within the scope of oral exam, it will be also discussed correlation of stress field in respect to geotectonic domains, recent seismicity and seismic hazards and risks.

20-G06 Course description	
Name of the course	***Igneous and metamorphic rocks: geotectonic-petrogenetic approach (4 ECTS) - teacher: Garašić, V.***
Goals of the course	• to present the theoretical models of global plate tectonics • to explain the modes of the correlation of the geochemical characteristics of magmatic rocks with the geotectonic setting of their formation • to present the characteristics of metamorphic rocks regarding their protolith, mineral and chemical composition, thermobarometry, P-T-t path and the geotectonic setting of formation • to demonstrate the ways of the interpretation of petrogenesis of magmatic and metamorphic rocks
Expected learning outcomes (levels 8.2)	**Set IU1: Petrogenesis of magmatic rocks (1,5 ECTS)** • to establish a relationship between geochemical characteristics of magmatic rocks and the processes of petrogenesis (0,5 ECTS) • to create a hypothesis for the occurrence of the given magmatic rocks in the distinct geotectonic setting (1 ECTS) **Set IU2: Petrogenesis of metamorphic rocks (1,5 ECTS)** • to establish a relationship between the mineral and geochemical characteristics of the metamorphic rocks, calculated thermobarometric values and P-T-t path with the processes of petrogenesis (0,5 ECTS) • to create a hypothesis for the occurrence of the given metamorphic rocks in the distinct geotectonic setting (1 ECTS) **Set IU3: Writing of report about petrogenesis of rocks (1 ECTS)** • to create a report about the petrogenesis of a given magmatic rock in the accordance with the plate tectonics theory (0,5 ECTS) • to create a report about the petrogenesis of a given metamorphic rock in the accordance with the plate tectonics theory (O,5 ECTS)
Course content	**Global plate tectonics:** from intracontinental rifting to post-collisional extension: theoretical models of global plate tectonics **Magmatic rocks:** Petrogenesis and geochemical discrimination of igneous rocks from the intracontinental rift zones within the plates of the continental lithosphere. Petrogenesis and geochemical discrimination of igneous rocks from ocean ridges (mid-ocean ridges and ridges in backarc basins). Petrogenesis and discrimination of igneous rocks from the supra-subduction settings (intra-oceanic arcs, fore-continent island arcs, continental-margin magmatic arcs). Petrogenesis and geochemical discrimination of igneous rocks from the intra-plate oceanic islands. Petrogenesis and geochemical characteristics of igneous rocks from the collision zones. Petrogenesis and geochemical discrimination of the post-collisional igneous rocks. **Metamorphic rocks:** methods of discrimination and determination of protolith composition. Phase stability diagrams of metamorphic minerals and metamorphic reactions. Thermobarometry and constructing of P-T-t paths of metamorphic rocks. Petrogenesis of thermally metamorphosed rocks. Petrogenesis and geotectonic setting of milonitized rocks. Petrogenesis and geotectonic setting of HP/LT dynamothermal metamorphic rocks from the subduction zones. Petrogenesis and geotectonic setting of Abukuma type HT/LP dynamothermal metamorphic rocks. Petrogenesis and geotectonic setting of the dynamothermal metamorphic rocks from the geotectonic setting with standard geothermobarometric gradients. Alterations and metamorphism in the oceanic near-ridge settings: a) hydrothermal ocean floor alterations, b) metamorphic sole.
Method of instruction	**Set IU1**

	1. Lectures, available in the form of Power Point presentations in pdf format (0,6 ECTS) 2. Exercises: the choice of the certain analytical research method, presentation of the obtained results and their interpretation (0,2 ECTS) 3. Learning and the preparation for the exam (0,7 ECTS) **Set IU2** 1. Lectures, available in the form of Power Point presentations in pdf format (0,6 ECTS) 2. Exercises: the choice of the certain analytical research method, presentation of the obtained results and their interpretation (0,2 ECTS) 3. Learning and the preparation for the exam (0,7 ECTS) **Set IU3** 1. Writing and presentation of a seminar (1 ECTS)
Evaluation of student performance	• Writing and presentation of a seminar • Oral exam – the test of theoretical knowledge • Oral exam – the test of the practical knowledge: the determination of the geotectonic-petrogenetic characteristics of a given rock on the basis of its chemical data

20-G07 Course description	
Name of the course	***Geochemistry of crustal rocks (3 ECTS)*** ***- teacher: Garašić, V.***
Goals of the course	• to get students acquainted with the diversity of geochemical composition of continental and ocean crust using main elements, trace elements and ratios of relevant radiogenic and stable isotopes • to demonstrate the processes causing geochemical diversity of crustal rocks • to present the ways of determination of geochemical composition of the crust and the mode of the result displays in the appropriate diagrams • to show the ways of the interpretation of geochemical composition of the crustal rocks
Expected learning outcomes (levels 8.2)	• to distinguish the geochemical composition of the continental crust from the ocean crust (0,6 ECTS) • to correlate the chemical composition of the sandstone with source rocks (0,6 ECTS) • to use the radiogenic Sr and Nd isotopes in the interpretation of the genesis of the crustal rock (0,6 ECTS) • to use oxygen and carbon isotopes in the interpretation of the genesis of carbonate rocks (0,6 ECTS) • to create a report about the processes influencing a geochemical composition of the crust for a given studied area (0,6 ECTS)
Course content	• Processes of the Earth's crust formation and the evolution of its chemical composition. • The distribution of the radioactive elements in the Earth's crust. • Average chemical composition of the continental crust. Granites and basalts of the continental crust. • Average chemical composition of the oceanic crust. Basalts of the mid-ocean ridges, gabbros and cumulates. • The chemical composition of the sands, shales, pelites and carbonates. • The interpretation of the distribution of the rare earth's elements and other trace elements in magmatic crustal rocks. • The variation of isotopic composition in the crust through the geologic time scale. The use of the correlation diagrams of Nd/Sr ratios in the recognition of the rocks being formed in the crust from those being formed in the mantle. The use of combined oxygen and carbon isotopes in the distinguishing between carbonate rocks of different origin.
Method of instruction	1. Lectures, available in the form of Power Point presentations in pdf format (1 ECTS) 2. Exercises: presentation of the results of the geochemical composition of a crust in different types of diagrams and their interpretation (0,4 ECTS) 3. Writing and presentation of a seminar (0,6 ECTS) 4. Learning and the preparation for the exam (1 ECTS)
Evaluation of student performance	• Writing and presentation of a seminar • Oral exam – the test of theoretical knowledge • Oral exam – the test of the practical knowledge: the interpretation of the geochemical characteristics of the crust using different types of diagrams

20-G08-1 Course description	
Name of the course	***Facies Research and Sedimentary Environment Models – Unit 1: Clastic Facies and Sedimentary Models (5 ECTS)*** ***- teacher: Aljinović, D.; Smirčić, D.***
Goals of the course	To define depositional processes and characteristic features within various clastic sedimentary environments. To define facies characteristics, specific architecture and origin of facies in particular sedimentary environments. To apply methods of facies analysis and to present depositional models.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able: 1. to explain the important facies features in the main clastic sedimentary environments; (1 ECTS) 2. to interpret peculiar facies features by referring on the major sedimentary processes or their origin; (1 ECTS) 3. to integrate facies into the sedimentary models and to present the facies model; (1 ECTS) 4. to argument/discuss the characteristics of the vertical sequence and to correlate it with the events and changes in the sedimentary environment; (1 ECTS) 5. to elaborate the facies analysis of the clastic sedimentary environments, related to hydrocarbon source and reservoir facies properties. (1 ECTS) 1.
Course content	**Clastic Facies and Sedimentary Models** Rock facies definitions. Facies relationship, associations and sequences. Elements of facies analysis and sequence stratigraphy. Continental, transitional and marine clastic depositional environments. Characteristics of modern analogues, sedimentary processes, sequences and models. Alluvial fans, rivers lakes, deltas, shallow siliciclastic seas, ramps and shelfs: facies, processes, characteristics, sequences and models. Deep sea clastic settings and facies – processes, sequences and models. Turbidity currents and fans. Transformation of initial gravity flow. Volcaniclastic facies - genesis, sequences, composition, and facies changes in vertical successions. Examples from seismic facies and sequences observed in the Adriatic subsurface.
Method of instruction	Course will be held by lectures, exercises and individual work of students as seminars and presentations. Teaching material will be available at the e-learning system Merlin. In the frame of auditory exercises, students will discuss and try to apply adequate examples from literature and will also interpret and propose depositional models or sequences for various depositional environments. Working on students' seminars will be completely individual, and the final results should be presented to the audience (student colleagues and instructors). **Clastic Facies and Sedimentary Models** Lectures (2 ECTS); Auditory exercises (1 ECTS); Making seminar presentation (1 ECTS); Learning and preparing for the final exam (1 ECTS).
Evaluation of student performance	Students are obligated to make a seminar individually, and to present it to the audience (student colleagues and the academicians) as well as answer to put questions. The final exam is oral. Student have to explain, interpret, argument and integrate the important tasks related to the main topics based on the literature examples or/and his/her own research results, Student will also have to answer instructor's questions.

20-G08-2 Course description	
Name of the course	***Facies Research and Sedimentary Environment Models – Unit 2: Carbonate Depositional Systems (5 ECTS)*** ***- teachers: Vlahović, I.; Barudžija, U.***
Goals of the course	To define depositional processes and characteristic features within carbonate depositional environments. To define facies characteristics, specific architecture and origin of facies in carbonate depositional environments.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able: 1. to analyze and present the characteristics, processes and changes in facies/microfacies within the carbonate depositional systems; 2. to integrate facies into the carbonate depositional model and to argument the depositional model applied; 3. to interpret aspects of the carbonate depositional environments and to apply them in geological explorations for hydrocarbons; 4. to design the procedures in the research of the carbonate depositional systems.
Course content	**Carbonate Depositional Systems** Cyclic sedimentation, carbonate cycles and sequences. Depositional sequences, the internal architecture of carbonate sequences and sequence stratigraphy. Types of carbonate platforms, the main controlling factors affecting carbonate sedimentation, relationship between the siliciclastic and carbonate depositional systems. Characteristics, processes, sequences and models of: a) shallow carbonate (platform) depositional systems; b) peritidal carbonate environments; c) coastal high-energy carbonate environments; d) carbonate shelf environments; e) reef-complex carbonate environments; f) deep-water and pelagic carbonate environments. Variations, characteristics and facies changes in vertical successions. A major part of the lectures will be illustrated by the examples from the Adriatic Carbonate Platform and its underlying and overlying successions. The most important examples of worldwide carbonate depositional systems will also be presented.
Method of instruction	The course will comprise lectures and student seminars with presentations. Teaching material will be available on the e-learning system Merlin. Students will present their seminars to the audience (fellow students and instructors).
Evaluation of student performance	Students have to make an individual seminar and present it to the audience (fellow students and instructors). During the final oral exam students will have to explain, interpret, argument and integrate knowledge related to the course topic based on the literature examples or/and his/her own research results and answer instructor’s questions.

20-G08-3 Course description	
Name of the course	***Facies Research and Sedimentary Environment Models – Unit 3: Principles of Facies Correlation (3 ECTS)*** ***- teacher: Aljinović, D.; Smirčić***
Goals of the course	To define facies and specific architecture and organization of facies in characteristic vertical successions (cycles and sequences). To explain the main issues related to facies correlation and to apply adequate correlation principles in analyzing sedimentary successions.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able: 1. to apply various criteria in correlation of facies; (0,5 ECTS) 2. to propose possibilities for correlation of vertical facies successions; (0,5 ECTS) 3. to propose adequate correlation criteria and to discuss the results of the correlation; (1 ECTS) 4. to integrate correlation of vertical sedimentary successions in the scope of sequence stratigraphy (1 ECTS)
Course content	**Principles of Facies Correlation** Facies relationships; Vertical facies associations; Cycles and sequences (rhythmic facies changes, various order cycles and sequences; definition of the sequence boundaries); High-resolution correlation and chronostratigraphy (time span assessment, significance of tephra layers, biostratigraphic zonation, FAD, LAD, different order cycles); Lithofacies markers; Condensed sections; Redox events; Biostratigraphic markers and biofacies modeling; Cyclostratigraphic approach to the Earth's history; Biological and evolutionary interdependence; Sequence stratigraphy and their record in sedimentary successions.
Method of instruction	Course will be held by lectures, exercises and individual work of students as seminars and presentations. Teaching material will be available at the e-learning system Merlin. In the frame of auditory exercises, students will discuss on correlation examples from literature, and will also interpret correlation principles. Working on students' seminars will be completely individual, and the final results should be presented to the audience (student colleagues and instructors). **IU3 Principles of Facies Correlation** Lectures (1 ECTS); Auditory exercises (1 ECTS); Making seminar presentation (0,5 ECTS); Learning and preparing for the final exam (0,5 ECTS).
Evaluation of student performance	Students are obligated to make a seminar individually, and to present it to the audience (student colleagues and the academicians) as well as answer to put questions. The final exam is oral. Student have to explain, interpret, argument and integrate the important tasks related to the main topics based on the literature examples or/and his/her own research results, Student will also have to answer instructor's questions.

20-G09-1 Course description	
Name of the course	***Diagenesis and paleopedology – Unit 1: Diagenesis and Diagenetic Practicum (5 ECTS)*** ***- teacher: Barudžija, U.***
Goals of the course	Explain the sedimentological, geochemical and mineralogical aspects and the processes of diagenesis. Demonstrate micropetrographical diagenetic analysis and time-sequence interpretation of the diagenetic processes. Demonstrate preparation, interpretation and applications of the diagenetic study.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able: • to critically evaluate the diagenetic aspects and processes in sediments; • to critically evaluate the time-sequence of the diagenetic processes; • to present observed diagenetic aspects and the time-sequence of the diagenetic processes; • to critically evaluate interpretations and applications of the diagenetic study; • to analyze micropetrographically the diagenetic features in sediments; • to set the hypothesis of the applied micropetrographic diagenetic study; • to prepare the applied micropetrographic diagenetic study.
Course content	**Diagenesis:** Mechanical, chemical and biogenic diagenetic processes: compaction, water displacement, reduction of porosity, cementation, dissolution, authigenesis, neomorphism, recrystallization, micritization, bioerosion. Diagenetic environments (subaerial to subaquatic, continental to marine, deep burial to uplifting environments). Clastic diagenesis, carbonate diagenesis, evaporitic diagenesis, siliceous sediments diagenesis, organic matter diagenesis. Early- and late-diagenetic processes in the various diagenetic environments and conditions. **Diagenetic Practicum:** The applied micropetrographic diagenetic study. Application of the diagenetic study in: sedimentary basins evolution research; sequence stratigraphy; hydrocarbon reservoirs research; aquifer studies; archaeological research; forensic analysis.
Method of instruction	**Diagenesis:** The course will be conducted through lectures and consultations, the exercises and the individual preparation of student seminars. Teaching material will be available at the e-learning Merlin system. As part of the auditory exercises, students will study examples from the literature and independently solve tasks on a given topic and then independently write a seminar paper. **Diagenetic Practicum:** As part of the diagenetic practicum, students will independently identify, classify and interpret various sediments using a polarizing microscope and produce a diagenetic study.
Evaluation of student performance	In diagenesis, students must prepare a seminar paper, and to present it to the other students and lecturer. The final exam is combined, written and oral. In the written part of the exam, on the literature example, student is required determine and interpret diagenetic features present and to interpret diagenetic processes involved, as well as their time-sequence. In the oral part of the exam, student is required answer the questions from the subject material. As a part of diagenetic practicum, student is required to describe and classify a set of sediment samples, and to determine their diagenetic features. The students should then interpret obtained results and create a diagenetic study with the help of additional data.

20-G09-2 Course description	
Name of the course	***Diagenesis and paleopedology – Unit 2: Paleopedology and Paleopedological Practicum (5 ECTS)*** ***- teacher: Durn, G..***
Goals of the course	Explain the processes and factors of soil and paleosol formation. Classify and explain the processes related to the burial of paleosols. Demonstrate the importance of paleosol research in paleoenvironmental, sedimentological and stratigraphic studies. Demonstrate importance of micromorphological analysis of paleosols using examples from the various geological ages. Prepare and apply the paleopedological study in geological investigations.
Expected learning outcomes (levels 8.2)	Upon completion of the learning process, student will be able: - to critically evaluate the micromorphology of paleosols; - to critically evaluate and to present the soil-forming and the soil burial-related factors and processes; - present the significance of paleosols in the paleoenvironmental, sedimentological and stratigraphic studies; - to critically evaluate paleosols from the various geological ages, as well as their interpretations and applications in paleosols studies; - to analyze micromorphologically the paleosols; - to set the hypothesis of the applied paleosols study; - to prepare the paleopedological study.
Course content	**Paleopedology:** Soil formation processes (indicators of physical, chemical and biological weathering). Soils and paleosols classifications. Main characteristics of paleosols (root traces, soil horizons, the structure and the texture of soil). Quaternary paleosols. Paleosols on major subaerial exposure surfaces (discordances). Paleosols in the sedimentary successions. Mapping of the paleosols and their nomenclature (paleoecological, sedimentological and stratigraphic studies). Alteration of the paleosols after burial (compaction, cementation, neomorphism, authigenesis, dissolution, dehydration, reduction, base exchange, carbonization). Factors of the soil formation. Climate (indicators of the rainfall, temperature and seasonality). Organisms (traces of organisms, traces of ecosystems, fossil preservation in paleosols). Relief (indicators of the past geomorphic setting, indicators of the past water table, interpretation of the paleocatenas). Parent material. Time (indicators of paleosol development). Examples of paleosols in different geological periods. The examples of the paleopedological studies in: sedimentology, stratigraphy, paleontology, ore deposits, paleoclimatology, paleogeography, archaeology, and in the research for the origin of life. **Paleopedological Practicum:** The applied micromorphological paleosols study (by using the polarising microscope and SEM). Application of paleopedology and micromorphology in various types of geological investigations.
Method of instruction	**Paleopedology:** Instruction will be conducted through lectures/consultations, auditory exercises, and the independent preparation of a seminar paper. The teaching materials and the activity plan will be available on the Merlin e-learning system. As part of the auditory exercises, students will study examples from the literature and independently solve tasks on a given topic and then independently write a seminar paper. **Paleopedological Practicum:** As part of the paleopedological practicum, students will independently identify, classify and interpret various paleosol specimens using a polarizing microscope and produce a paleopedological study.
Evaluation of	In paleopedology, students must prepare a seminar paper on paleopedology and present it to

student performance	their peers and the lecturer. The examination consists of a written and an oral part. In the written part of the examination, the student must interpret the micromorphology of the paleosol using an example from the literature. In the oral part of the examination, the student must answer questions from the subject material. As part of the paleopedological practicum, the student is required to describe and classify a series of paleosol samples in micromorphological terms and describe their paleopedological characteristics. The students should then interpret the results obtained and create a paleopedological study with the help of additional data.

20-G10-1 Course description	
Name of the course	***Environmental mineralogy and geochemistry – Unit 1: Mineralogy, geochemistry and soil protection (6 ECTS)*** ***-teachers: Durn, G., Kisić, I.***
Goals of the course	Explain the importance of mineralogy and geochemistry for the processes taking place in the environment and of soil as one of its components. Explain the basic properties, structural and surface physico-chemical characteristics of soil. Compare and explain the physico-chemical and biochemical processes in the soil. Plan the application of mineralogical and geochemical investigations to solve problems in soil protection.

Expected learning outcomes (level 8.2)	Upon completion of the learning process, the doctoral student will be able to: - to analyze the mineral and geochemical properties of different soil types; - to critically evaluate the interpretation and application possibilities of mineralogical and geochemical soil investigations; - to formulate a hypothesis about the applied mineralogical and geochemical soil studies; - to write a mineralogical and geochemical soil study; - to analyze the project documentation, which is a prerequisite for the restoration, reclamation and remediation of damaged soils; - to analyze the most important levels of damage in the soil - to critically evaluate soil protection measures (damage inventory, permanent monitoring, information system) and recultivation methods.

Course content	Soil forming processes (physical weathering indicators, chemical weathering indicators, biological weathering indicators). Basic properties, structural and surface physico-chemical properties of pedogenic minerals. Mineralogical and geochemical properties of different soil types. Soil as an environmental compartment. Interpretation of mineralogical and geochemical soil composition. Application of mineralogical and geochemical soil investigations in environmental protection (industry, agriculture). The role of soil. Classification and types of contamination as a form of soil degradation. Erosion of the soil. Soil contaminants – potentially toxic metals, polycyclic aromatic hydrocarbons, persistent organic pollutants in soil and hydrocarbons in soil. Basic principles of soil sampling. Legislation in the Republic of Croatia and some other EU countries. Technology of remediation of contaminated soils. Biological methods of remediation.
Method of instruction	Teaching will be conducted through lectures/consultations and practical tasks. The teaching materials (power point presentation in pdf format, individual tasks and scientific literature) will be made available via the Merlin e-learning system. The exercises will be organized as auditory exercises. As part of the auditory exercises, students solve tasks on a given topic independently or in teams and write a seminar paper.
Evaluation of student performance	Students must write a seminar paper on the topic and present it to other colleagues and the lecturer. The examination consists of a written and an oral part. In the written part of the examination, the student must solve a practical task from the subject area. In the oral part of the examination, the student must answer questions from the subject matter.

20-G10-2 Course description	
Name of the course	***Environmental mineralogy and geochemistry – Unit 2: Recent sediments mineralogy and geochemistry (3 ECTS)*** ***-teacher: Sondi, I.***
Goals of the course	- to explain the importance of mineralogy and geochemistry in environmental processes. - to explain the basic characteristics, structural and surface physico-chemical properties of geological materials (soils, sediments, mining waste). - to show and to explain physico-chemical and biochemical processes in soil / sediment / mining waste. - to demonstrate the application of mineralogical and geochemical studies in solving environmental problems.

Expected learning outcomes (level 8.2)	- to determine the type of recent sediments and their mineralogical and geochemical characteristics; - to determine the surface-physical-chemical characteristics of recent sediments; - to determine their absorption capacity for pollutants based on the surface physical-chemical characteristics of the sediment.

Course content	**Recent sediments mineralogy and geochemistry:** The role of physico-chemical and biological processes (biomineralization) in the formation of recent sediments. Formation of small particles and active surfaces. Classification and characterization methods of micro- and nano-mineral particles in recent sediments. The basic mineralogical, geochemical and surface physico-chemical properties of sediments. Basic physico-chemical interaction processes of sediment mineral surfaces and organic and inorganic compounds. Pollutants and contaminants in sedimentary systems. Micro and nano-particles in contaminant binding-, transport- and disposal- processes in recent environments. Recent sediments as contaminant holder.
Method of instruction	Teaching will be conducted through lectures / consultations and practical assignments. Teaching materials (Power Point presentation in pdf format, assignments and scientific literature) will be placed in learning management system Merlin. Exercises will be organized as auditory exercises. Within the auditory exercises, students will have to solve assignments on a given topic alone or in a team and will prepare a seminar.
Evaluation of student performance	Students have to prepare a seminar paper and present it to other colleagues and a teacher. In the written exam, the student should solve the practical task of the topic being discussed.

20-G10-3 Course description	
Name of the course	***Environmental mineralogy and geochemistry – Unit 3: Mining waste and its impact on the environment (3 ECTS)*** ***-teacher: Mileusnić, M.***
Goals of the course	- to explain the importance of mineralogy and geochemistry in environmental processes. - to explain the basic characteristics, structural and surface physico-chemical properties of mining waste. - to show and to explain physico-chemical and biochemical processes in mining waste. - to demonstrate the application of mineralogical and geochemical studies in solving environmental problems.

Expected learning outcomes (level 8.2)	- to analyze mineral and geochemical characteristics of mining waste; - to predict the possible impact of mining waste on the environment and human health; - to recommend methods of control / remediation of mining waste; - to create mineral-geochemical study of mining waste.

Course content	**Mining waste and its impact on the environment:** Definition, characterization and classification of mining waste. Mineral and geochemical characteristics of different mining waste types. Potentially toxic elements. Chemical reactions (acidification, neutralization). Processes (microbiological activities, formation and dissolution of secondary minerals, coprecipitation, adsorption / desorption). Impact of mining waste on the quality of water, soil and air. Prediction of acidification. Monitoring. Sulfide oxidation control. Remediation methods. Impact of mining waste on human health (exposure paths and route of entry, bioaccessibility and bioavailability).
Method of instruction	Teaching will be conducted through lectures / consultations and practical assignments (seminar). Teaching materials will be placed in learning management system Merlin.
Evaluation of student performance	Students have to prepare a seminar paper and present it to other colleagues and a teacher. The exam is oral.

20-G10-4 Course description	
Name of the course	***Environmental mineralogy and geochemistry – Unit 4: Fate of contaminants in the unsaturated zone (3 ECTS)*** ***-teacher: Ružičić, S.***
Goals of the course	- to explain the importance of mineralogy and geochemistry of solute transport processes in unsaturated zone - to show and to explain process of solute transport in unsaturated zone

Expected learning outcomes (level 8.2)	- to critically evaluate processes of contaminant transport in unsaturated zone; - to analyze the contaminant transport processes in the unsaturated zone; - to perform a batch sorption experiment in the laboratory on samples from the unsaturated zone; - to create sorption isotherms from experimental results.

Course content	**Fate of contaminants in the unsaturated zone:** The contaminant transport processes in the unsaturated zone (advection, sorption, dispersion). The sorption of potentially toxic metals processes in an unsaturated zone (examples). Field and laboratory experiments of contaminant transport in unsaturated zone. Isothermal curves.
Method of instruction	Teaching will be conducted through consultations and practical assignments. Teaching materials (Power Point presentation in pdf format, assignments and scientific literature) will be placed in the learning management system Merlin. Exercises will be organized as auditory exercises. Within the auditory exercises, students will have to solve assignments on a given topic.
Evaluation of student performance	Students have to prepare a project assignment. The exam consists of an oral part.

20-G11 Course description	
Name of the course	***Ore deposits and industrial minerals (6 ECTS)*** ***- teachers: Borojević Šoštarić, S.; Garašić, V.***
Goals of the course	• to define the processes of metallogenesis in magmatic, sedimentary and metamorphic rocks with special overview of genesis of industrial minerals • to explain the factors influencing the processes of metallogenesis and their change through the geological time • to exhibit the distribution of ore deposits in the relation to the plate tectonics • to present primary structural and chemical properties of the selected industrial minerals and their post-crystallization processes changes (exsolutions, intergrowth, alterations) • to define critical raw materials for the EU related to specific stages of the industrial processes • to present impact of the mineral properties on the behaviour of the mineral during the industrial processes
Expected learning outcomes (levels 8.2)	Upon completion of the learning process the student will be able: **Set IU1: Ore deposits and plate tectonics (V. Garašić) 1 ECTS** • to establish a relationship between geochemical characteristics of magmatic rocks and the processes of petrogenesis (0,5 ECTS) • to create a hypothesis for the occurrence of the given magmatic rocks in the distinct geotectonic setting (0,5 ECTS) **Set IU2: Industrial minerals and their use (S. Borojević Šoštarić) 5 ECTS** • to integrate influences of the post-crystallization processes on the structural and chemical properties of the selected industrial minerals (1 ECTS) • to select suitable minerals for industrial production on selected example (1.5 ECTS) • to predict behaviour of the minerals and mixtures during the industrial process (1.5 ECTS) • to link structural and chemical properties with the behaviour of the minerals and mixtures during the industrial process (1 ECTS)
Course content	**Ore deposits and plate tectonics:** The relationship between the origin of crustal rocks and ore-forming processes. Magmas and metallogenesis. Sedimentary rocks and metallogenesis. Metamorphic rocks and metallogenesis. The formation of industrial mineral deposits. Metamorphic rocks and metallogenesis. The importance of hydrothermal fluids in magmatic, sedimentary and metamorphic rocks. The main factors influencing the process of global metallogenesis: a) the evolution of hydrosphere and atmosphere and related redox processes, weathering and erosion, b) decrease in global heat production through geological time, c) global tectonic processes comprising rate of continental growth through geological time, the nature of mantle convection, eustatic sea-level changes. Metallogeny through time: the Archean Eon, the Proterozoic Eon, the Phanerozoic Eon. Tectonic cycles and metallogenesis. An overwiew of the ore deposits in relation to their tectonic setting of formation. Ore deposits in extensional settings: intracontinental rifts (Africa), intercontinental rifts (Red Sea), mid-ocean ridges, back arc basins. Ore deposits in compressional settings: the zones of subduction and the zones of collision. Ore deposits at passive continental margins, in intracontinental basins, in cratons. **Industrial minerals and their use:**

	Industrial deposit types. Structural and chemical properties of the most common oxides, hydroxides, carbonates, sulphates, silicates. Post-crystallization processes, crystallizations discontinuity, exolution in the spinel group, pyroxene group, amphibole group, feldspar group. Alteration product of the silicate minerals. Thermal behaviour of the phyllosilicates. Commercial properties and uses of natural zeolites. Abrasives. Insulation materials. Mineral pigments and fillers. Plasters. Mineral fertilizers. Ceramics including fire-resistant materials, high-temperature processes and products. Raw materials for glass manufacture, types of glass and their properties. Raw materials for cement production, types of cement, constituents of the cement clinker and the products of their hydration. Critical minerals for the EU. Section selected by the student.
Method of instruction	**Set IU1** 4. Lectures, available in the form of Power Point presentations in pdf format (0,4 ECTS) 5. Exercises: the choice of the certain analytical research method, presentation of the obtained results and their interpretation (0,2 ECTS) 6. Writing and presentation of a seminar (0,2 ECTS) 7. Learning and the preparation for the exam (0,2 ECTS) **Set IU2** 1. Lectures, available in the form of Power Point presentations in pdf format (0,5 ECTS) 2. Exercises: the choice of the certain analytical research method, presentation of the obtained results and their interpretation (0,5 ECTS) 3. Writing and presentation of a seminar (2 ECTS) 4. Learning and the preparation for the exam (2 ECTS)
Evaluation of student performance	**Set IU1** Writing and presentation of a seminar Oral exam – the test of theoretical knowledge Oral exam – the test of the practical knowledge on example of one ore deposit **Set IU2** Writing and presentation of a seminar Oral exam – the test of theoretical knowledge Oral exam – the test of the practical knowledge on example of one industrial deposit

20-GI01 Course description	
Name of the course	***Karst Aquifers (5 ECTS)*** ***- teacher: Parlov, J.***
Goals of the course	- present physical and chemical processes in karstification, - present groundwater flow in karst aquifers, - define geochemical properties karst groundwater, - present water-tracing methods, - define principles of karst water sources protection, - identify a journal articles, develop questions and guide the discussions about karst aquifers.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the doctoral candidate will be able to: - construct conceptual models for karst systems (0,5 ECTS), - analyze geochemical data of karst groundwater to determine properties of karst aquifer (1 ECTS), - correlate the relationship between karst system development (dissolution) and flow dynamics (0,3 ECTS), - draw connections between karst science, hydrology and geomorphology (0,2 ECTS), - formulate principles of proper protection of karst water sources (2 ECTS), - design water-tracing in karst terrains (2 ECTS), - evaluate the soundness of the results and conclusions of scientific data (0,5 ECTS).
Course content	The relationships of karst with general geomorphology and hydrogeology (global distribution of karst). Dissolution and precipitation kinetics of the karst rocks. The infuence of climate and climatic change on karst development. Measurements in the field and laboratory. Classification and characteristics of karst aquifers. Applicability of Darcy's law to karst aquifers. Freshwater – saltwater interface. Analysis of karst drainage systems. Surface survey techniques. Spring hydrograph analysis. Spring chemograph analysis. Water-tracing techniques. Computer modelling of karst aquifers. Karst water resources management. Karst hydrogeological mapping. Human impacts on karst water. Groundwater vulnerability, protection and risk mapping.
Method of instruction	Lectures and exercises (1 ECTS). Project task (2 ECTS). Seminar (1 ECTS). Preparation for the oral exam (1 ECTS)
Evaluation of student performance	Seminar. Oral exam.

20-GI02 Course description	
Name of the course	***Hydraulics of groundwater (3 ECTS)*** ***- teacher: Duić, Ž.***
Goals of the course	present hydrogeological parameters as a function of aquifer geological setting, present different types of flow net in aquifers, define range of validity for Darcy's linear flow and hydraulic threshold gradient, present heterogeneity and anisotropy of hydraulic conductivity, present flow in unsaturated zone
Expected learning outcomes (levels 8.2)	analyze the different types of flow in the aquifer system with regard to the scale (spatial and temporal), (0,5 ECTS) evaluate the influence of basic physical properties of fluid and porous media on hydrogeological parameters, (0,5 ECTS) present the relationship between the equipotential surfaces and the streamlines in complex flow conditions (heterogeneity and anisotropy), (0.5 ECTS) evaluate the methods of interpretation and application of forms for quantification of hydrogeological parameters, (1 ECTS) analyze fluid flow through an usaturated zone with an emphasis on the influence of spatial and temporal scales, and the constraints that hamper the direct application of Darcy's law (0.5 ECTS)
Course content	Parametric expression of water-bearing properties of the environment. Hydrodynamic description of flow in porous media. The general meaning and limits of validity of Darcy's law. Filtration parameters field, filtration tensor, the main axis of filtration, the transformation of the coordinate system, the ellipse and ellipsoid of hydraulic conductivity, speed in the direction of the gradient. Stream functions. Physical meaning and interpretation of the flow net, the boundary conditions. Modeling methods. Analytical method for the specific boundary conditions and identification of hydrogeological parameters. Numerical modeling methods. Water in unsatureted soil. Saline intrusion in homogeneous and layered aquifers. Course content and methodology of the course is focused on exploring and understanding the ways of quantifying the effect of the general properties of water-bearing geological environment on the behavior of groundwater, and the acquisition of skills to address the specific issues of groundwater flow.
Method of instruction	Lectures or Consultations (2 ECTS) and writing a seminar (1 ECTS).
Evaluation of student performance	Students are required to prepare a seminar paper and present it to colleagues and teachers. The exam consists of an oral part within which the student should answer the questions of the subject matter.

20-GI03 Course description	
Name of the course	***Mathematical modelling of contaminant transport in groundwater systems (5 ECTS)*** ***- teachers: Posavec, K.; Nakić, Z.***
Main goals	- present transport processes of contaminants in nature, - present characteristics of advective-dispersive transport and transport with geochemical reactions with emphasis on linear and nonlinear sorption processes, - process parameters of advection-dispersion equation including geochemical reactions, - define mathematical models i.e. governing transport equations with initial and boundary conditions, - define analytical and/or numerical methods for mathematical models solution, - present model calibration, verification and sensitivity analysis.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the doctoral candidate will be able to: (5 ECTS) - formulate processes of contaminant transport in nature *(1 ECTS)* – Z. Nakić, - connect transport processes with parameters of advection-dispersion equation including geochemical reactions *(1 ECTS)* – Z. Nakić, - form mathematical models with initial and boundary conditions for specific hydrogeological problems *(1 ECTS)* – Z. Nakić i K. Posavec, - suggest analytical or numerical methods for solution of mathematical models *(1 ECTS)* – K. Posavec, - design transport models *(1 ECTS)* – K. Posavec.
Outlines /module content	A framework for application of groundwater contaminant transport models. Theoretical foundations of contaminant transport processes. Goals of contaminant transport modelling. Conceptual models. Examples of application of stratigraphic modelling and 2D and 3D geostatistical methods in building conceptual models. Advective-dispersive transport in groundwater. Geochemical reactions in groundwater. Model input parameters: flow parameters, transport parameters, chemical parameters. Mathematical models of contaminant transport in groundwater: governing equations, initial and boundary conditions. Analytical and numerical solutions of mathematical models. Spatial and temporal discretization in contaminant transport models. Calibration, verification and validation of contaminant transport models. Sensitivity analysis. Types and sources of uncertainty in contaminant transport simulations.
Method of instruction	Teaching will be conducted through lectures (2 ECTS), computer exercises (1 ECTS) and student project (2 ECTS)
Evaluation of student performance	1. Student project: Development of conceptual and mathematical contaminant transport model for specific example and presentation of solution with application of analytical and/or numerical methods. 2. Oral exam

<table>
<tr><th colspan="2">20-GI04 Course description</th></tr>
<tr><td>Name of the course</td><td>Characterization of engineering geological units (5 ECTS)
- teachers: Mihalić Arbanas, S.; Krkač, M.</td></tr>
<tr><td>Goals of the course</td><td>- To explain genetic soil types, rock weathering and weathering profiles
- To show subjects of scientific research in the domain of characterization of engineering geological units
- To explain advanced scientific researches related to selected research field: 1 – Soil characteristics depending on mineralogical composition; 2 – Intact rock characteristics depending on mineralogical composition; 3 – Rock mass characteristics depending on mineralogical composition
- To discuss with student relevant methods of scientific researches related to selected research field
- To guide student through study of relevant methods of scientific research related to selected research field</td></tr>
<tr><td>Expected learning outcomes (levels 8.2)</td><td>Learning outcomes 1: Introduction (0,5 ECTS) – S. Mihalić Arbanas
- To differ genetic soil types, rock weathering and weathering profiles and to select criteria for interpretation of engineering geological units
Learning outcomes 2: Soil characteristics depending on mineralogical composition (1,5 ECTS) – S. Mihalić Arbanas
- To collect scientific publications on soil characteristics depending on mineralogical composition
- To critically estimate methods of research of soil characteristics depending on mineralogical composition
- To present results of scientific research on soil characteristics depending on mineralogical composition
Learning outcomes 3: Intact rock characteristics depending on mineralogical composition (1,5 ECTS) – M. Krkač
- To collect scientific publications on s intact rock oil characteristics depending on mineralogical composition
- To critically estimate methods of research of intact rock characteristics depending on mineralogical composition
- To present results of scientific research on intact rock characteristics depending on mineralogical composition
Learning outcomes 4: Rock mass characteristics depending on mineralogical composition (1,5 ECTS) – M. Krkač
- To collect scientific publications on s rock mass oil characteristics depending on mineralogical composition
- To critically estimate methods of research of rock mass characteristics depending on mineralogical composition
- To present results of scientific research on rock mass characteristics depending on mineralogical composition</td></tr>
<tr><td>Course content</td><td>i. Genetic soil types;
ii. Rock weathering and weathering profiles;
iii. Research approaches of the interrelationship between soil composition and characteristics relevant to characterization of engineering geological units (soil composition and engineering properties, soil fabric, water in soil);
iv. Research approaches of the interrelationship between intact rock composition and characteristics relevant to characterization of engineering geological units (intact rock composition and engineering properties, intact rock structure, intact rock weathering);
v. Research approaches of the interrelationship between rock mass composition and characteristics relevant to characterization of engineering geological units (weathering classifications for different rock types, genesis and characteristics of discontinuities, rock mass characterization).</td></tr>
</table>

Method of instruction	**Introduction to characterization of engineering geological units with examples of scientific research (0,5 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS) Learning (0,2 ECTS) **Soil characteristics depending on mineralogical composition (1,5 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Intact rock characteristics depending on mineralogical composition (landslides, erosion) (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Rock mass characteristics depending on mineralogical composition (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS)
Evaluation of student performance	**Introduction to characterization of engineering geological units with examples of scientific research (0,5 ECTS) – S. Mihalić Arbanas** 1. Oral exam **Soil characteristics depending on mineralogical composition (1,5 ECTS) – S. Mihalić Arbanas** 1. Discussion about scientific researches, results and methods, related to selected research field **2.** Seminar/essay: writing of review based on available data from literature related to selected research field **Intact rock characteristics depending on mineralogical composition (landslides, erosion) (1,5 ECTS) – M. Krkač** 1. Discussion about scientific researches, results and methods, related to selected research field **2.** Seminar/essay: writing of review based on available data from literature related to selected research field **Rock mass characteristics depending on mineralogical composition (1,5 ECTS) – M. Krkač** **1.** Discussion about scientific researches, results and methods, related to selected research field **2.** Seminar/essay: writing of review based on available data from literature related to selected research field

* Depending on interest of students, it is possible to organize workshop on selected research field of characterization of engineering geological units (1 ECTS)

20-GI05 Course description	
Name of the course	***Hydrology (5 ECTS)*** ***- teacher: Pavlić, K.***
Goals of the course	- To present the processes and features of the hydrological cycle in the atmosphere, on the ground and below the surface. - To demonstrate water runoff as a response to rainfall by various methods. - To relate the impact of precipitation on surface water runoff. - To present the elements of spectral and statistical analysis in hydrology. - To demonstrate spectral and statistical analysis on hydrological and meteorological data.
Expected learning outcomes (levels 8.2)	Upon completion of the process of learning the doctoral student will be able to: Hydrology – lectures (2 ECTS) - Analyze the processes and features of the hydrologic cycle. (0,2 ECTS) - Critically evaluate the individual processes in the hydrological cycle and their importance for the process of surface runoff. (0,3 ECTS) - Present the elements of spectral and statistical analysis in hydrology. (1,5 ECTS) Hydrology – exercises (3 ECTS) - Set hypothesis of the influence of meteorological features and processes on surface water runoff. (0,5 ECTS) - Apply spectral and statistical analysis on hydrological and meteorological data. (2 ECTS) - Submit the results of own research. (0,5 ECTS)
Course content	Hydrological processes in the hydrological cycle. Water in the atmosphere. Water vapor and water vapor transport in the atmosphere. Precipitation. Precipitation formation. Spatial distribution of precipitation. Evaporation. Water on the surface. Fluid mechanics of free surface flow. Surface flow. Water wave transformation (Muskingum method). Water below the surface. Infiltration. Groundwater outflow and groundwater runoff. Surface flow as a response to precipitation. Streamflow response at the catchment scale. Stationary linear flow response (unit hydrograph). Stationary nonlinear response. Spectral and statistical analysis. Random variables and probability. Probability distribution functions for discrete and continuous variables. Fourier analysis.
Method of instruction	Lectures (2 ECTS), seminar task (3 ECTS).
Evaluation of student performance	Seminar task and oral exam

20-GI06 Course description	
Name of the course	***Natural stone and aggregate (6 ECTS)*** ***- teachers: Maričić, A.***
Goals of the course	- to **evaluate** natural stone with regard to decorative, geological, technical, technological and economic criteria - to **correlate** the influence of geological features in the deposits to the research, utilization, evaluation, development and exploitation of natural stone and aggregate - to **analyze** the correlation of stones properties with durability, quality and usability of natural stone and aggregate
Expected learning outcomes (level 8.2)	Upon completion of the learning process, a student will be able to: **Learning outcomes 1:** ***Deposits of natural stone and aggregate (3 ECTS)*** 1. to classify stone varieties with respect to its properties and usability (0,5 ECTS) 2. to assess the geological properties of deposits that affects the exploration, exploitation and utilization of natural stones and aggregates (1 ECTS) 3. to evaluate the natural stone considering the decorative, geological, technical, technological and economic criteria (1,5 ECTS) **Learning outcomes 2: Durability of natural stone and aggregate (3 ECTS)** 1. to analyze rock varieties with respect to mineralogical, petrographic, physical, mechanical, chemical, technical and technological properties (1,5 ECTS) 2. to critically evaluate the impact of stones properties on its durability and possible application (1 ECTS) 3. to estimate causes of stone deterioration in under the conditions of installation depending on the method of utilization and performance of stone structures (0,5 ECTS)
Course content	**Learning outcomes 1: Deposits of natural stone and aggregate** Classification of natural stone and aggregates. Criteria for evaluation of natural stone (decorative, geological, technical, technological and economical). The importance of understanding the genesis, geological and petrographic characteristics of deposits for the production of building materials with emphasis on the deposits of natural stone and aggregate and sand and gravel. Special aspects of exploration, development and exploitation of the deposits of natural stone and aggregate. The importance, possibilities and methods of influence solving of petrographical and technical features of deposits during research, development and exploitation. The influence of geological factors on the stability, durability, efficiency and optimization during exploitation in the deposit of natural stone and aggregate. Determining the quality of mineral raw material in the deposit and its impact on methodology, dynamics and geometry of excavation. The impact of position of excavation front on the fragmentation of material and excavation. Economic aspects of natural stone and aggregate deposits research and assessment. **Learning outcomes 2: Durability of natural stone and aggregate** The importance of determining mineralogical, petrographical, physical, mechanical and chemical properties and their impact on the quality and utilization of stone. Impact and correlation of properties and quality, durability and usability of stone. The impact of homogeneity, heterogeneity and anisotropy on the properties and durability of stone. The durability of the stone built-in in the urban environment with emphasis on the functionality and constructive solution. The basic factors of physical, chemical and biological decay of embedded stone. The importance of testing the durability of stone to freezing, salt crystallization and thermal changes. The devastating effect of water in the stone. The activity of plants and microorganisms on the durability of stone.
Method of instruction	Teaching will be conducted through lectures, exercises and seminar work. Lectures from selected chapters will be held. The course will have elements of e-

	learning (lecture materials in PDF format, plan of action will be on the Merlin e-learning system). Exercises will be held in auditoria, laboratory (solving of practical and theoretical tasks and programs) and field work. Field work will be based on a review of built-in varieties of natural stone and aggregates (in Zagreb and its surroundings) and visit of the most important deposits of natural stone and aggregates around the city of Zagreb. Within the course, students will prepare a seminar with topic related to the course and presented it to colleagues and teachers. ***Ad LO1:*** *Lectures (0,3 ECTS); Exercises (1 ECTS); Preparation and presentation of seminar work (1 ECTS); Learning and preparing for the exam (0,7 ECTS).* ***Ad LO2:*** *Lectures (0,3 ECTS); Exercises (1 ECTS); Preparation and presentation of seminar work (1 ECTS); Learning and preparing for the exam (0,7 ECTS).*
Evaluation of student performance	1. Preparation and presentation of written seminar with discussion 2. Oral exam - presentation of the results of students research and answering the questions from the subject matter

20-GI07 Course description	
Name of the course	***Engineering geological zonation and prognostic geohazard maps (7 ECTS)*** ***- teachers: Bernat Gazibara, S.; Mihalić Arbanas, S.***
Goals of the course	- To explain principles and scales of engineering geological zonation and derivation of prognostic geohazard maps - To show subjects of scientific research in the domain of engineering geological zonation and derivation of prognostic geohazard maps - To explain advanced scientific researches related to selected research field: 1 – Thematic engineering geological maps; 2 – Prognostic maps of active geomorphological processes (landslides, erosion); 3 – Statistical methods for derivation of geohazard susceptibility maps; 4 – Seismic-geotechnical microzonation - To discuss with student relevant methods of scientific researches related to selected research field - To guide student through study of relevant methods of scientific research related to selected research field
Expected learning outcomes (levels 8.2)	**Learning outcomes 1: Introduction (1 ECTS) – S. Mihalić Arbanas** - To evaluate principles and to select scales of engineering geological zonation and derivation of prognostic geohazard maps **Learning outcomes 2: Thematic engineering geological maps (1.5 ECTS) – S. Mihalić Arbanas** - To collect scientific publications on thematic engineering geological maps - To critically estimate methods of derivation of thematic engineering geological maps - To present results of scientific research on thematic engineering geological maps in the form of synthesis **Learning outcomes 3: Prognostic geohazard maps (landslides, erosion) (1.5 ECTS) – S. Mihalić Arbanas** - To collect scientific publications on prognostic geohazard maps (landslides, erosion) - To critically estimate methods of derivation of prognostic geohazard maps (landslides, erosion) - To present results of scientific research on prognostic geohazard maps (landslides, erosion) **Learning outcomes 4: Statistical methods for derivation of geohazard susceptibility maps (1.5 ECTS) – M. Krkač** - To collect scientific publications on statistical methods for derivation of geohazard susceptibility maps - To critically estimate statistical methods for derivation of geohazard susceptibility maps - To present results of scientific research on statistical methods for derivation of geohazard susceptibility maps **Learning outcomes 5: Seismic-geotechnical microzonation (1.5 ECTS) – M. Krkač** - To collect scientific publications on methods of seismic-geotechnical hazard assessment - To critically estimate methods of seismic-geotechnical hazard zonation - To present results of scientific research on seismic-geotechnical hazard zonation
Course content	vi. Principles of engineering geological zonation; vii. Derivation of thematic engineering geological maps (maps of potential and constraints) and its application in the domain of physical and urban planning, construction and civil protection; viii. Types of prognostic maps (susceptibility maps, hazad maps, vulnerability maps, risk maps and multi-hazard maps); ix. Statistical methods (bivariate and multivariate statistics, artificial neural

	networks) of derivation of active geomorphological processes susceptibility maps (slides, falls, flows, erosion, subsidence etc.); x. methods of seismic-geotechnical hazard microzonation.
Method of instruction	**Introduction to engineering geological zonation and prognostic geohazard maps with examples of scientific research (1 ECTS) – S. Mihalić Arbanas** Lectures (0.3 ECTS) Learning (0.7 ECTS) **Thematic engineering geological maps (1.5 ECTS) – S. Mihalić Arbanas** Lectures (0.3 ECTS), Learning (0.2 ECTS) Seminar (1 ECTS) **Prognostic geohazard maps (landslides, erosion) (1.5 ECTS) – S. Mihalić Arbanas** Lectures (0.3 ECTS), Learning (0.2 ECTS) Seminar (1 ECTS) **Statistical methods for derivation of geohazard susceptibility maps (1.5 ECTS) – M. Krkač** Lectures (0.3 ECTS), Learning (0.2 ECTS) Seminar (1 ECTS) **Seismic-geotechnical microzonation (1.5 ECTS) – M. Krkač** Lectures (0.5 ECTS) Seminar (1 ECTS)
Evaluation of student performance	**Introduction to engineering geological zonation and prognostic geohazard maps with examples of scientific research (1 ECTS) – S. Mihalić Arbanas** 2. Oral exam **Thematic engineering geological maps (1.5 ECTS) – S. Mihalić Arbanas** 3. Discussion about scientific researches, results and methods, related to selected research field **4.** Seminar/essay: writing of review based on available data from literature related to selected research field **Prognostic geohazard maps (landslides, erosion) (1.5 ECTS) – S. Mihalić Arbanas** 3. Discussion about scientific researches, results and methods, related to selected research field **4.** Seminar/essay: writing of review based on available data from literature related to selected research field **Statistical methods for derivation of geohazard susceptibility maps (1.5 ECTS) – M. Krkač** 3. Discussion about scientific researches, results and methods, related to selected research field **4.** Seminar/essay: writing of review based on available data from literature related to selected research field **Seismic-geotechnical microzonation (1.5 ECTS) – M. Krkač** 1. Discussion about scientific researches, results and methods, related to selected research field **2.** Seminar/essay: writing of review based on available data from literature related to selected research field

* Depending on interest of students, it is possible to organise workshop on selected research field of engineering geological zonation and derivation of prognostic geohazard maps (1 ECTS)

20-GI08 Course description	
Name of the course	***Engineering geological models (4 ECTS)*** ***- teachers: Krkač, M.; Mihalić Arbanas, S.***
Goals of the course	- To explain types of engineering geological models - To show subjects of scientific research in the domain of engineering geological models - To explain advanced scientific researches related to selected research field: 1 – Conceptual engineering geological models; 2 – Observational engineering geological models - To discuss with student relevant methods of scientific researches related to selected research field - To guide student through study of relevant methods of scientific research related to selected research field
Expected learning outcomes (levels 8.2)	**Learning outcomes 1: Introduction (1 ECTS) – M. Krkač** - To select different approaches of modelling in engineering geological investigations and to evaluate their results **Learning outcomes 2: Conceptual engineering geological models (1,5 ECTS) – S. Mihalić Arbanas** - To collect scientific publications on thematic of conceptual engineering geological models - To critically estimate conceptual methods for engineering geological modelling - To present results of scientific research on thematic of conceptual engineering models in the form of synthesis **Learning outcomes 3: Observational engineering geological models (1,5 ECTS) – M. Krkač** - To collect scientific publications on thematic of observational engineering geological models - To critically estimate observational methods for engineering geological modelling - To present results of scientific research on thematic of conceptual engineering models in the form of synthesis
Course content	**Engineering geological models:** xi. Types of engineering geological models and their application xii. Modelling approaches in engineering geology xiii. Conceptual engineering geological models (model scale, processing, analyses and interpretation of input data) xiv. Observational engineering geological models (types of input data, analyses and interpretation of input data, modelling approaches)
Method of instruction	**Introduction to Engineering geological models (1 ECTS) – M.Krkač** Lectures (0,3 ECTS) Learning (0,7 ECTS) **Conceptual engineering geological models (1,5 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Observational engineering geological models (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS)
Evaluation of student performance	**Introduction to engineering geological models with examples of scientific research (1 ECTS) – M. Krkač** 3. Oral exam **Conceptual engineering geological models (1,5 ECTS) – S. Mihalić Arbanas** 5. Discussion about scientific researches, results and methods, related to selected research field 6. Seminar/essay: writing of review based on available data from literature

	related to selected research field **Observational engineering geological models (1,5 ECTS) – M. Krkač** 5. Discussion about scientific researches, results and methods, related to selected research field 6. Seminar/essay: writing of review based on available data from literature related to selected research field

* Depending on interest of students, it is possible to organize workshop on selected research field of engineering geological zonation and derivation of prognostic geohazard maps (1 ECTS)

20-GI09 Course description	
Name of the course	***Application of remote sensing and monitoring in Engineering geology (8 ECTS) - teachers: Krkač, M.; Bernat Gazibara, S.***
Goals of the course	- To explain types of sensors for remote sensing and monitoring of active geomorphological processes - To show subjects of scientific research in the domain of application of remote sensing in investigation of active geomorphological processes - To show subjects of scientific research in the domain of application of monitoring in investigation of active geomorphological processes - To explain advanced scientific researches related to selected research field: 1 – Remote sensing of active geomorphological processes in site specific investigations; 2 – Remote sensing of active geomorphological processes in regional scale investigations; 3 – Monitoring of active geomorphological processes in site specific investigations; 4 – Monitoring of active geomorphological processes in regional scale investigations - To discuss with student relevant methods of scientific researches related to selected research field - To guide student through study of relevant methods of scientific research related to selected research field
Expected learning outcomes (levels 8.2)	**Learning outcomes 1: Introduction (1 ECTS) – S. Mihalić Arbanas** - To select different types of sensors for remote sensing and monitoring of active geomorphological processes and to evaluate their results **Learning outcomes 2: Remote sensing of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** - To collect scientific publications on thematic of remote sensing of active geomorphological processes in site specific investigations - To critically estimate methods of remote sensing of active geomorphological processes in site specific investigations - To present results of scientific research on thematic of remote sensing of active geomorphological processes in site specific investigations in the form of synthesis **Learning outcomes 3: Remote sensing of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** - To collect scientific publications on thematic of remote sensing of active geomorphological processes in regional scale investigations - To critically estimate methods of remote sensing of active geomorphological processes in regional scale investigations - To present results of scientific research on thematic of remote sensing of active geomorphological processes in regional scale investigations in the form of synthesis **Learning outcomes 4: Monitoring of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** - To collect scientific publications on thematic of monitoring of active geomorphological processes in site specific investigations - To critically estimate methods of monitoring of active geomorphological processes in site specific investigations - To present results of scientific research on thematic of monitoring of active geomorphological processes in site specific investigations in the form of synthesis **Learning outcomes 5: Monitoring of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** - To collect scientific publications on thematic of monitoring of active geomorphological processes in regional scale investigations - To critically estimate methods of monitoring of active geomorphological processes in regional scale investigations - To present results of scientific research on thematic of monitoring of active geomorphological processes in regional scale investigations in the form of

	synthesis **Learning outcomes 6: Statistical analyses of monitoring data (1,5 ECTS) – M. Krkač** - To collect scientific publications on thematic of statistical analyses of monitoring data - To critically estimate methods of statistical analyses of monitoring data - To present results of scientific research on thematic of statistical analyses of monitoring data
Course content	**Application of remote sensing and monitoring in Engineering geology:** xv. Types of sensors (camera, radar, scanner) and their use in remote sensing of active geomorphological processes (landslides, erosion, accumulation, subsidence) xvi. Types of sensors (geodetical, geotechnical, hydrological and seismological) and their use in monitoring of active geomorphological processes (landslides, rockfalls, topples, debris flows and lateral spreads) xvii. Remote sensing of geomorphological processes in site specific scale (terrestrial LiDAR, photogrammetry) xviii. Remote sensing of geomorphological processes in regional scale (airborne LiDAR, inSAR, photogrammetry) xix. Monitoring (geodetical, geotechnical, hydrological and seismological) of geomorphological processes in site specific scale xx. Monitoring of geomorphological processes in regional scale (inSAR) xxi. Statistical analyses of monitoring data
Method of instruction	**Introduction to remote sensing and monitoring in Engineering geology with examples of scientific research (1 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS) Learning (0,7 ECTS) **Remote sensing of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Remote sensing of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Monitoring of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Monitoring of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS) **Statistical analyses of monitoring data (1,5 ECTS) – M. Krkač** Lectures (0,3 ECTS), Learning (0,2 ECTS) Seminar (1 ECTS)

Evaluation of student performance	**Introduction to remote sensing and monitoring in Engineering geology with examples of scientific research (1 ECTS) – S. Mihalić Arbanas** 1. Oral exam **Remote sensing of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** 1. Discussion about scientific researches, results and methods, related to selected research field 2. Seminar/essay: writing of review based on available data from literature related to selected research field **Remote sensing of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** 1. Discussion about scientific researches, results and methods, related to selected research field 2. Seminar/essay: writing of review based on available data from literature related to selected research field **Monitoring of active geomorphological processes in site specific investigations (1,5 ECTS) – M. Krkač** 1. Discussion about scientific researches, results and methods, related to selected research field 2. Seminar/essay: writing of review based on available data from literature related to selected research field **Monitoring of active geomorphological processes in regional scale investigations (1,5 ECTS) – S. Mihalić Arbanas** 3. Discussion about scientific researches, results and methods, related to selected research field 4. Seminar/essay: writing of review based on available data from literature related to selected research field **Statistical analyses of monitoring data (1,5 ECTS) – M. Krkač** 1. Discussion about scientific researches, results and methods, related to selected research field 2. Seminar/essay: writing of review based on available data from literature related to selected research field

* Depending on interest of students, it is possible to organize workshop on selected research field of engineering geological zonation and derivation of prognostic geohazard maps (1 ECTS)

20-GI10 Course description	
Name of the course	***Groundwater monitoring (3 ECTS)*** ***- teacher: Duić, Ž.***
Goals of the course	present the organization of monitoring and measuring devices used in different aquifer systems present different examples of technical performance of piezometers depending on the complexity of the observed aquatic system, define the conditions and limits for sampling, present examples of organized monitoring.
Expected learning outcomes (levels 8.2)	analyze the way of organization and monitoring implementation in complex hydrogeological conditions, (0,25 ECTS) evaluate the impact of spatial (especially vertical) and time scale on the monitoring system, (0,5 ECTS) present different methods of monitoring and limitations of certain techniques and devices (0,25 ECTS) evaluate the results of the monitoring in terms of its reliability and justification for the purpose of the research (0,5 ECTS) analyze different versions of technical design of observation facilities and achieved monitoring results, (0,25 ECTS) set a hypothesis and implement a monitoring project, (0,25 ECTS) set up and perform groundwater monitoring project, (1 ECTS)
Course content	Monitoring and its interaction with natural groundwater system. Scale effect in analyzing of hydrogeological phenomena. Water level transmission on local and regional scale and its distribution in heterogeneous aquifers. Scale effect at different boundary condition. Role of monitoring in identifying groundwater systems, quantifying resources and forecasting problems. Design of observing wells in heterogeneous aquifers. Groundwater sampling for chemical and bacteriological analysis and their meaning in space and time scale. Examples of successful and unsuccessful monitoring in specific conditions. This course is oriented in introduction of students to real meaning of data colected in monitoring systems, and also in development of skills and abilities necessary for successful projecting of groundwater monitoring.
Method of instruction	Lectures or Consultations (2 ECTS) and writing a seminar (1 ECTS).
Evaluation of student performance	Students are required to prepare a seminar paper and present it to colleagues and teachers. The exam consists of an oral part within which the student should answer the questions of the subject matter.

20-GI11 Course description	
Name of the course	***Operational research in hydrogeology (5 ECTS)*** ***- teacher: Posavec, K..***
Goals of the course	- present the development of operational research in hydrogeology, - describe the conceptualization of natural groundwater systems, - present analytical and numerical models for flow problems, - present LP models in hydrogeology, - present analytical and numerical solutions of solute transport equations.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the PhD candidate will be able to: - develop conceptual model of specific groundwater systems (2,5 ECTS), - define initial and boundary conditions and select appropriate flow equation (0,5 ECTS), - suggest methods for solving flow problem (0,5 ECTS), - define the objective function and constraints for specific hydrogeological system (0,5 ECTS), - design transport model (0,5 ECTS), - suggest methods for solving transport problem (0,5 ECTS).
Course content	Groundwater flow modelling: conceptualizing natural groundwater systems, selection of mathematical solutions, identifying initial and boundary conditions, analytical models for flow problems, numerical models for flow problems: finite difference model, finite element model. LP models. Contaminant transport modelling: conceptual models, transport equation, initial and boundary conditions in transport models, analytical modelling methods, numerical modelling methods. Computer codes: MODFLOW and FEFLOW. Computer code selection for specific hydrogeological case studies. Discussions about case studies through literature.
Method of instruction	Lectures (0,5 ECTS), exercises (0,5 ECTS), studying examples from scientific journals and development of conceptual and mathematical model for specific example (4 ECTS).
Evaluation of student performance	1. Written exam (development of conceptual and mathematical model for specific example) 2. Oral exam

20-GI12 Course description	
Name of the course	***Concepts of groundwater protection and remediation (5 ECTS)*** ***- teachers: Nakić, Z. and Posavec, K.***
Main goals	- present sources of contamination and groundwater contaminants, - present research approaches to contaminated groundwater systems, - define characterization methods of contamination and asses contamination risks, - present monitoring methods for contaminated aquifer systems, - present methods for groundwater remediation.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the doctoral candidate will be able to (5 ECTS): - classify sources of contamination and groundwater contaminants (1 ECTS) – Z. Nakić, - combine conventional and integrated approach in research of contaminated groundwater systems (1 ECTS) – Z. Nakić, - predict risks of contamination (1 ECTS) – Z. Nakić i K. Posavec, - develop monitoring systems for contaminated aquifers (1 ECTS) – K. Posavec, - suggest methods for groundwater remediation (1 ECTS) – K. Posavec.
Outlines /module content	The most common sources of contamination and groundwater contaminants; Characterization of contaminated groundwater systems; Risk assessment of groundwater contamination; Application of mathematical methods in the characterization and assessment of the risk of groundwater contamination; Conventional approach to investigations of contaminated groundwater systems; Integrated approach to investigations of contaminated groundwater systems; Necessary data for development of remediation project of contaminated groundwater systems; Research approaches and methods: surface recording, geophysical methods, drilling and sampling; Measures to remove contaminants from the groundwater systems; Methods for containing the contaminants in place (Slurry walls, Sheet pile walls, Surface seals and surface drainage, Hydrodynamic controls, Stabilization and solidification); Attenuating the possible hazard by institutional controls; Methods for removing the contaminants from the ground (Excavation and ex situ treatment, Conventional pump and treat methods, Interceptor systems, Soil-vapour extraction, Air sparging); and advanced in-situ methods (Intrinsic bioremediation, Bioventing and bioslurping, Reactive barrier systems); Alternative technologies of groundwater remediation; Monitoring of contaminated groundwater systems.
Method of instruction	Teaching will be conducted through lectures (3 ECTS) and seminar (2 ECTS)
Evaluation of student performance	1. Seminar paper: Application of the method(s) for remediation of contaminated groundwater systems; example on representative case study 2. Oral exam

20-GI13 Course description	
Name of the course	***Isotope hydrology (4 ECTS)*** ***-teacher: Kovač, Z.***
Goals of the course	The student will acquire knowledge about: • Basic principles in isotope geochemistry. • Fundamentals of isotope hydrology. • Roles and importance of isotopes in the hydrological cycle. • Applications of stable and radioactive isotopes in hydrologic and hydrogeochemical research. • Sampling and isotope analyses. • Interpretation of isotope data.

Expected learning outcomes	• To apply fundamental knowledge of isotope geochemistry and hydrology in hydrological and hydrogeochemical research (2 ECTS). • To sample and prepare water samples for different chemical and isotope analyses (0.5 ECTS). • To quantify and analyse groundwater and surface water interaction (0.5 ECTS). • To define nitrate origin in groundwater (0.5 ECTS). • Groundwater dating and estimation of groundwater velocities using radioactive isotopes (0.5 ECTS).

Course content	• Basic principles in isotope geochemistry. • Fundamentals of isotope hydrology. • Hydrological cycle and isotopes. • Isotope effects and isoscapes. • Applications of stable isotopes in hydrological research. • Isotope, hydrogeochemical and statistical data interpretation. • Radioactive isotopes and groundwater dating. • Water sampling, sample preparation, isotope ratio mass spectrometry and laser spectroscopy.
Method of instruction	Lectures and exercises (1 ECTS), project assignment (1 ECTS), seminar paper (1 ECTS) and preparation for the oral exam (1 ECTS).
Evaluation of student performance	Seminar paper and oral exam.

20-NI01 Course description	
Name of the course	***Well planning and drilling technology (10 ECTS)*** ***- teachers: Gaurina-Međimurec, N.; Pašić, B.***
Goals of the course	- present of planning process for different types of oil, gas and geothermal wells; - define drilling regime and different drilling technology; - present advantages and limitations of drilling horizontal, multilateral and extended reach wells; - present objective and subjective parameters that affect design; - elaborate well logging types ant their use in boreholes; - define the analytical and numerical models to optimize tool selection for successful drilling performance, - define alternate procedures and safety measures while monitoring and performing project; - synthesize input for performing and evaluating project; - present the criteria for the design of drilling fluid (mud) and cement slurry for specific drilling conditions; - present the optimization of the wellbore cleaning and casing cementing; - carry out laboratory testing of mud and cement slurries;
Expected learning outcomes (levels 8.2)	**Learning outcomes 1: Well design (4 ECTS) – PhD. Zdenko Krištafor, full professor** - revise geological, geophysical and thermodynamic conditions to predict their impact on the quality of modeling vertical, directional or horizontal wells (1 ECTS); - integrate analytical and numerical models with realistic parameters in terms of project management (1 ECTS); - develop a project matching planned and real-time parameters during drilling a well (1 ECTS); - valorize the realization of the well project (1 ECTS). **Learning outcomes 2: Wellbore Cleaning and Well Cementing Optimization (4 ECTS) – PhD. Nediljka Gaurina-Međimurec full professor** - comparison of different drilling technology (1 ECTS); - design a mud and cement slurry for specific wellbore conditions (1 ECTS); - design cementing geothermal, gas and horizontal wells (1 ECTS); - optimize the cuttings carrying capacity of the drilling fluids and casing cementing (1 ECTS). **Learning outcomes 3: Drilling of horizontal and multilateral wells (2 ECTS) – PhD. Borivoje Pašić, assistant professor** - well trajectory planning for different type of wells (1 ECTS); - selection of appropriate methods for drilling of directional well (1 ECTS).
Course content	**Learning outcomes 1: Well design** Input data for planning different types of oil, gas and geothermal wells: offset well data, electric logs, mud logging, rock samples and cores, well testing results, seismic data; designing of optimal well trajectory; selection of appropriate drilling regime; determining casing setting depths; drillstring design, torque and drag analysis, kick-off point determining, casing design; wellhead and BOP design; expected working pressures, well logging and their frequency; rig equipment requirements; based on drilling program, material and services specifications; planning of well costs;. parameters affecting the wellbore stability; techno-economic indicator of drilling process; project evaluation.

	Learning outcomes 2: Wellbore Cleaning and Well Cementing Optimization Casing drilling; optimizing cementing for different pressure and temperature conditions; optimizing wellbore cleaning and hydraulic power on bit; hydraulic design; optimizing drilling fluid rheological properties; efficiency of drilling rig surface fluid processing system; monitoring and control of drilling fluid properties; causes of gas migration after primary cementing and methods for their prevention; effect of pressure and temperature on set cement properties; geothermal and gas well cementing; remedial cementing; specific of horizontal well cementing; cement job evaluation; laboratory testing of mud and cement slurry; drilling fluid selection criteria. **Learning outcomes 3: Drilling of horizontal and multilateral wells** Application of different mathematical models in design optimal trajectory for different types of wells; comparison between sliding and rotation technique in drilling of directional well; operating characteristics of downhole motors; measure while drilling and trajectory surveys.
Method of instruction	**Learning outcomes 1: Well design (4 ECTS):** Lectures (2,5 ECTS), Seminar work and presentation (1,5 ECTS) **Learning outcomes 2: Wellbore Cleaning and Well Cementing Optimization (4 ECTS):** Lectures (2,5 ECTS), Seminar work and presentation (1,5 ECTS) **Learning outcomes 3: Drilling of horizontal and multilateral wells (2 ECTS):** Lectures (0,5 ECTS), Seminar work and presentation (1,5 ECTS)
Evaluation of student performance	**Learning outcomes 1: Well design** - Student project / seminar work: Creating a conceptual solution for a certain example from the petroleum engineering practice by applying analytical and / or numerical methods - making an independent project. Result publication in the form of a scientific or professional article, depending on the quality of the obtained results; - Oral exam. **Learning outcomes 2: Wellbore Cleaning and Well Cementing Optimization** 1. Student project / seminar work: Creating a conceptual solution for a certain example from the petroleum engineering practice by applying analytical and / or numerical methods - making an independent project. Result publication in the form of a scientific or professional article, depending on the quality of the obtained results; 2. Oral exam. **Learning outcomes 3: Drilling of horizontal and multilateral wells** 1. Student project / seminar work: Creating a conceptual solution for a certain example from the petroleum engineering practice by applying analytical and / or numerical methods - making an independent project. Result publication in the form of a scientific or professional article, depending on the quality of the obtained results; 2. Oral exam.

20-NI02 Course description	
Name of the course	***Hydrocarbon reservoir development methods (10 ECTS)*** ***- teachers: Vulin, D.; Kurevija T.***
Goals of the course	- Define the optimum well pattern to achieve maximum macroscopic oil displacement coefficient based on known of rock and fluid properties - Define the optimal number of production wells according to economic criteria and adjust the dynamics of hydrocarbon production based on the present regime of oil recovery - Compare and recommend the appropriate method for increasing the hydrocarbon recovery - Predict the recovery from gas-condensate reservoirs - Detect opportunities and define the criteria for storing natural gas and carbon dioxide in different geological structures, aquifers and depleted oil and gas fields - Show technological and physical differences in approach to the development of conventional and unconventional deposits
Expected learning outcomes (levels 8.2)	- Design a network of production and injection wells for hydrocarbon reservoirs, taking into account the properties of reservoir rocks and fluids and recovery increase. (1 ECTS) - **prof. D.Vulin** - Develop the concept of underground storage of natural gas or carbon dioxide based on the static and dynamic parameters of the formation or parameters from a mature hydrocarbon reservoir and technical-technological criteria. (1 ECTS) - **prof. D.Vulin** - Perform case analysis by comparing analytical and simulation results and to exclude methods that provide less reliable prediction of hydrocarbon production (1 ECTS) - **prof. D.Vulin** - Build a compositional simulation model for fluid injection analysis for Enhanced Oil Recovery (EOR) (1 ECTS) - **prof. D.Vulin** - Perform statistical analysis and the assessment of the feasibility of a particular simulation case (1 ECTS) - **prof. D.Vulin** - Select candidate wells for hydraulic fracture according to reservoir and production data (1 ECTS) - **prof. D.Vulin** - Propose and design secondary recovery method to maintain the reservoir pressure, based on the dominant primary regime; the regime of dissolved gas, gas caps and / or waterdrive regime. (1 ECTS) **– prof. T.Kurevija** - Analyze production decline curves and predict the cumulative recovery and recovery rates. (1 ECTS) **– prof. T.Kurevija** - Connect the variation of gas consumption with dynamics of gas removal from natural gas underground storage balance the dynamics of consumption and supply of gas (1 ECTS) **– prof. T.Kurevija** - Generalize the production predictions by analytical and simulation methods to estimate the feasibility an particular method (1 ECTS) **– prof. T.Kurevija**
Course content	Selection of well spacing and well pattern according to fluid and reservoir properties and type of oil and gas recovery regime. Optimum well spacing for oil reservoirs with water drive (aquifer) and gas cap regime. Optimum number of wells in oil fields with dissolved gas regime according to economic criteria and adaptation of the dynamics of hydrocarbon production according to the established regime in the reservoir. Analysis of Enhanced Recovery possibilities (methods) based on detected critical parameters that affect each enhanced recovery method. Design and analysis for application of enhanced (improved) oil recovery methods. Pressure decline data analysis. Possibilities for natural gas storage into: depleted gas and oil reservoirs, aquifers, salt caverns and increased capacity of pipeline network. Selection criteria and design of the underground storage of carbon dioxide. Performance verification of underground gas storage facilities. By conventional, i.e. primary and secondary methods, only part of the total hydrocarbon reserves is recovered. The main obstacles to greater recovery are the

	increase in fluid viscosity, water intakes from the aquifer or fluid and rock properties, such as unfavorable fluid mobility. To achieve economically feasible additional recovery from the reservoir of unfavorable properties, knowledge about enhanced hydrocarbon recovery is required. Regarding the above-mentioned features, the following topics will be covered: thermal processes (steam injecting, cyclic steam injection, increased thermal mobility of petroleum), chemical methods (polymer-flood, emulsions, surface active agents or fluids with high coefficient of sorption), gas injection methods under mixing conditions (hydrocarbon gases and carbon dioxide above minimum miscibility pressure, nitrogen injection). Economic risk assessment of the application of each of the tertiary methods based on the overview of the EOR screening. Estimates of time-spatial fluid saturation changes, i.e. the mobility ratio and the chemical composition of the fluids (phases). Comparison of stochastic methods and analytical correlations of properties, statistical distribution of reservoir data, numerical methods of estimation of reservoir properties. Technological and physical differences in approach to the development of unconventional deposits, compositional simulation of a reservoir, fractured reservoir simulation and a double porosity / double permeability simulation.
Method of instruction	*Teaching will be conducted through lectures/consultations and auditory and practical exercises. Practical exercises include independent work on the computer using specialized simulation software (Schlumberger Petrel RE, Schlumberger Eclipse, PetEx MBal and Prosper, available at workstations at the faculty). Teaching materials and activities will be on the Merlin e-Learning system. As part of the auditory exercises, students will independently solve tasks on a given topic, review and collect professional and scientific literature.* * Lectures = **3 ECTS** * Exercises and practical exercises on the computer = **4 ECTS** * Seminar: Consultation, research and study of professional and scientific literature, data collection and processing, preparation and independent writing of scientific work = **3 ECTS**
Evaluation of student performance	*Students are obligated to prepare a seminar paper and present it to colleagues (PhD students) and teachers. Seminar work must be in the form of a scientific paper that is suggested to be published in a scientific journal. The verbal exam will help to determine the final grade.*

20-NI03 Course description	
Name of the course	***Workover optimization and reservoir stimulation (6 ECTS)*** ***- teachers: Pašić, B.; Brkić, V.***
Goals of the course	- define the well productivity parameters; - present systematic approach to well completion and workover; - present specificity of horizontal and multilateral well completions and workovers; - present specificity of "intelligent" completion; - determination of the type of reservoir rock formation damage by laboratory measurements; - present the mechanics of hydraulic fracturing in horizontal wells; - present modelling of hydraulic fractures propagation in unconventional reservoirs; - explain procedure for frack-pack well completion; - define the approach for evaluation or well completion, workovers and formation damage remove procedure.
Expected learning outcomes (levels 8.2)	**Learning outcomes 1: Well Completion and Workover Optimization (3 ECTS) – PhD. Borivoje Pašić, assistant professor** - propose the methods for well completion considering it purpose and subsurface conditions (0,5 ECTS); - select "intelligent" completion systems of certain well or field (1 ECTS); - plain horizontal and multilateral well completion and workover (0,5 ECTS); - evaluate the performance of the applied well completion and workover processes (1 ECTS). **Learning outcomes 2: Contemporary Reservoir Treatment Methods (3 ECTS) – PhD. Vladislav Brkić, assistant professor** - create hydraulic fracture propagation models for unconventional reservoirs (0,5 ECTS); - propose the methods of conventional reservoirs treatment considering to and intensity of formation damage, kind of rock, and well conditions (0,5 ECTS); - valorise the results of hydraulic fracturing in horizontal wells (1 ECTS); - evaluate efficacy of frack-pack process on certain well or field (1 ECTS).
Course content	**Learning outcomes 1: Well Completion and Workover Optimization** Systematic approach to well completion and workover. Well completion design. Wellheads for multiple completions (more than one production string). Tubing string design and joint selection for high pressure, high temperature and multiple completions. Movements and forces in tubing/packer systems for combined completions. Specificity of "intelligent" completion; downhole equipment for pressure, temperature and volume measuring. Specificity of horizontal well completions, multilateral well completion and extended reach well completion. Well workover planning. Economic aspects of optimal well completion and workover design. **Learning outcomes 2: Contemporary Reservoir Treatment Methods** Well performance: productivity index, the parameters influencing productivity index, permeability and skin factor influence, permeability and skin factor determining by transient pressure analyses, components of the skin effect, flow efficiency and damage ratio. Alterations near-wellbore zone permeability: causes, diagnoses, treatment methods. Near wellbore damage categories: natural damages, induced damages, laboratory identification of damages, complete core analyses, acid solubility tests, treatment techniques to remove damage, acids for matrix acidizing. Matrix acidizing procedures: matrix acidizing of carbonate formations, matrix acidizing of sandstone formations, treatment specificities of oil, gas and water injection wells. Hydraulic fracturing mechanics: in-situ stresses of

	the reservoir rocks, rock mechanic fundamentals, hydraulic fracture mechanics. Hydraulic fracture models: KGD model, PKN model, radial model. Fracturing fluid losses: fluid loss coefficient, Carter's equation, proppant transport and distribution in the fracture, heat transfer from the reservoir to the fracture. Fracturing fluids: linear and crosslinked water based gels, gelled oil, emulsions, fracturing fluids rheological properties, fluid loss properties. Proppant: required physical properties, types of proppant, optimization of hydraulic fracturing process. Combination of hydraulic fracturing and gravel pack: "frac - pack" completion.
Method of instruction	**Learning outcomes 1: Well Completion and Workover Optimization (3 ECTS):** Lectures (1,5 ECTS), Seminar work and presentation (1,5 ECTS) **Learning outcomes 2: Contemporary Reservoir Treatment Methods (3 ECTS):** Lectures (1,5 ECTS), Seminar work and presentation (1,5 ECTS)
Evaluation of student performance	**Learning outcomes 1: Well Completion and Workover Optimization** - Student project / seminar work: Creating a conceptual solution for a certain example from the petroleum engineering practice by applying analytical and / or numerical methods - making an independent project. Result publication in the form of a scientific or professional article, depending on the quality of the obtained results; - Oral exam. **Learning outcomes 2: Contemporary Reservoir Treatment Methods** 3. Student project / seminar work: Creating a conceptual solution for a certain example from the petroleum engineering practice by applying analytical and / or numerical methods - making an independent project. Result publication in the form of a scientific or professional article, depending on the quality of the obtained results; 4. Oral exam.

20-NI04 Course description	
Name of the course	***Environmental protection in petroleum industry (6 ECTS)*** ***- teachers: Hrnčević, L.; Novak Mavar, K.***
Goals of the course	- present petroleum industry activities which can potentially result with contamination/pollution of the environment, potential contaminants/polluters in petroleum industry and waste from petroleum industry activities, - present hydrocarbon behaviour and movement when spilled on water and/or soil or evaporated to air (emissions) along with the remediation methods, - present waste management in petroleum industry (solidification, stabilization, bioremediation, thermal treatment, well injection, mud pits remediation etc.) onshore and offshore, - define the criteria for waste injection formation and waste injection well selection, present technology of waste treatment and injection to selected wells and present monitoring methods for petroleum industry waste injection, - present legal regulations in field of environmental protection in petroleum industry
Expected learning outcomes (levels 8.2)	- classify waste generated during petroleum industry activities, after accidental situations and after remediation activities (1 ECTS)-Gaurina Međimurec - predict behaviour and movement of spilled hydrocarbons, develop contingency plan and select remediation methods for specific oil pollution situations (1.5 ECTS)- Hrnčević - design waste reduction activities and recommend petroleum industry waste treatment methods (1.5 ECTS)- Gaurina Međimurec - classify wells and geological formations suitable for waste injection, design technological solutions for waste preparation (treatment) and injection and plan monitoring activities during and after petroleum industry waste injection (1.5 ECTS)- Gaurina Međimurec - organize petroleum industry activities and waste management according to legal regulations (0.5 ECTS)- Gaurina Međimurec, Hrnčević
Course content	Impact of the petroleum industry activities and its waste on the environment. Contamination and pollution caused by petroleum industry activities and oil pollution remediation methods. Oil spill detection methods, monitoring methods and oil spill consequences. Behaviour of oil spill in different environmental conditions. Oil spill modelling. Contingency plans. Definition of petroleum industry waste, waste from accidental situations and waste formed during oil spill remediation activities. Petroleum industry waste catalogue. Waste prevention and waste quantity reduction. Sources of toxicity of petroleum industry technological waste. Petroleum industry technological waste management and management of waste created during oil spill remediation activities (waste treatment, reuse and recycling). Waste treatment methods (solidification, stabilization, bioremediation, thermal treatment, well injection, mud pits remediation etc.). Waste disposal methods (surface and/or underground disposal). Waste treatment and well injection technology. Injection well selection criteria. Injection well construction and completion. Injection well hydraulic integrity and maximum allowable working pressures. Waste injection monitoring. Offshore petroleum industry waste management. Environmental protection and waste management legislation. Field work.
Method of instruction	Lectures: 20 hours (0.7 ECTS) Exercises: 10 hours (0.3 ECTS) Individual work: - Term paper: 80 hours (2 term papers) (3 ETCS) - Studying: 60 hours (2 ECTS)
Evaluation of student performance	1. Evaluation of writing and presenting term papers 2. Oral exam.

20-NI05 Course description	
Name of the course	***Energy transformations and energy planning (6 ECTS)*** ***- teacher: Perković, L.***
Goals of the course	**to present** features of all relevant energy transformations in the existing and upcoming energy systems through the energy-mass balance and corresponding influences on market price of energy **to present** features of inclusion of energy efficiency measures on primary energy supply and final consumption of energy **to demonstrate** optimization methods for the assesment of projects leading towards the more rational use of energy **to define** the base energy scenario of national energy systems to analyse results of modelling of national energy systems through the validation against available data **to define** hypothetical transitional scenarios of the existing into upcoming national energy systems for the purpose of long-term energy planning and development of energy strategies **to demonstrate** multi-criteria optimization for the simultaneous optimization of structural design and energy management of various forms of energy systems
Expected learning outcomes (levels 8.2)	Group LO 1: Energy transformations (3 ECTS): 1. **to analyse** mass-energy balance of energy transformations in energy systems 2. **to relate** the market price of energy assembled on the free market with the thermo-physical properties of energy transformations of market participants 3. **to set hypothesis** on the necessary investments in energy systems for the need of increasing the energy efficiency and rationalization of use of energy Group LO 2: Energy planning (3 ECTS): 1. **to design** individual and national energy systems 2. **to write** techno-economic analysis related to the investment in energy efficiency projects and smart use of energy resources 3. **to set hypothesis** on the possible scenarios of the development of national energy systems with special analysis of primary energy supply and pollutant emissions
Course content	**Energy transformations:** transformations in conventional power plants, combined heat and power, renewable energy sources, synthetic- and bio-fuels. Correlation between energy transformations and market price of energy. Influence of mass and energy balance on national energy systems. Rational use of energy, energy efficiency and implementation of energy efficient technologies. Project evaluation in the field of energy efficiency. Optimization methods for smart energy resource planning. Smart energy systems and management. **Energy planning:** mapping of energy demand and available resources. Designing the model of national energy system base scenario, simulation of the model with the use of energy planning tool. Assesment of integration of renewables and other upcoming energy technologies (4^{th} generation district heating, electric transport, synthetic- and biofuels) on the change in primary energy supply. Verification of results through the verification parameters: total primary energy supply (by energy type), final consumption of energy and pollutant emissions. The role of energy storage, techno-economic evaluation of seasonal storage integration into existing energy systems. Reservoir as energy storage. Single- and multiobjective optimization of structural design and energy management of various forms of energy systems.

Method of instruction	<u>Group LO 1: Energy transformations (3 ECTS):</u> • lectures (10 hrs) + exercise (5 hrs): 15 hrs in total (0.5 ECTS) • literature survey and preparation of seminar: approximately 450 pages or 45 hrs of individual work (1.5 ECTS) • writing seminar: 10,000 - 13,000 characters: 25 - 28 hrs (1 ECTS) <u>Group LO 2: Energy planning (3 ECTS):</u> • lectures (10 hrs) + exercise (5 hrs): 15 hrs in total (0.5 ECTS) • literature survey and preparation of seminar: approximately 450 pages or 45 hrs of individual work (1.5 ECTS) • writing seminar: 10,000 - 13,000 characters: 25 - 28 hrs (1 ECTS) Lectures will be organized as multimedia presentation of relevant theory and appropriate case studies. Seminars will be organized as individual work combined with the consultations with the course teacher.
Evaluation of student performance	Students are obligated to write the seminar related to the course topics: energy transfromations and energy planning. Seminar also has to be related to the research field of the student's doctorate topic (if available) and it's form must follow the usual form of scientific papers with the following chapters included: literature survey, methodology, synthesis and analysis of results and conclusion. The course grade will depend also on the quality of the verbal defense of the seminar (duration: max 15 minutes)

20-NI06 Course description	
Name of the course	***Reservoir rock and fluid characterization for fluid flow modelling (4 ECTS) - teacher: Vulin, D.***
Main goals	- Interpret measurements of static rocks properties - Interpret and compare special rock analysis data measured by different methods - Use advanced reservoir and PVT simulator capabilities for initialization and matching of numerical models and laboratory measurement results. - Construct and, based on the research of published scientific papers, organize the system of measurement and interpretation of rocks properties by non-standard methods (e.g. injectivity in damaged formation, determination of the quality of sealing rocks, etc.) - Make a study of the feasibility of hydrocarbon recovery project by a certain tertiary (EOR) method based on laboratory data - Demonstrate and argue the strengths and weaknesses of a laboratory method when upscaling data at the reservoir scale. - Present the economic justification of a particular laboratory method. - Correlate the measured fluid and measured rock properties (by case studies and hypothetically upscaled models). - Integrate elements of PVT study for a specific case of production from hydrocarbon reservoir, geothermal deposits, and peak, seasonal and of permanent storage of gases.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the doctoral candidate will be able to: - Critically evaluate and set the conditions for rock sample testing (sample preparation conditions, analysis types, and measurement conditions) ***0.25 ECTS*** - Demonstrate an integrated set of analyses for recovery, injection, and storage of fluids in formation and to and justify interpreted measurement results. ***0.25 ECTS*** - Analyze the static and dynamic properties of rocks using standard equipment for measuring permeability, porosity and capillary pressure. ***0.25 ECTS*** - Modify standard measurements for the purpose of innovative rock properties testing. ***1 ECTS*** - Critically evaluate key parameters that significantly change the result of laboratory data interpretation. ***0.25 ECTS*** - Create numerical PVT model based on laboratory data. ***1 ECTS*** - Develop an analytical and numerical model of laboratory fluid injecting tests in the sample (core). ***0.5 ECTS*** - Set hypotheses and define key assumptions for flow model upscaling (i.e. fluid injection and recovery) near-wellbore scale and on the reservoir scale. ***0.25 ECTS*** - Create a database of the investigated literature relevant to the narrow area of analysis of a reservoir parameter (mobility, injectivity, puncture, etc.). ***0.25 ECTS***
Outlines /module content	Traditional "black-oil" PVT formulation. Fluid properties: composition, phase behavior and relevant PVT parameters. Standard laboratory experiments and application of data for black-oil calculations. Use the Equation of State (EOS) to calculate black-oil properties. Application to other fluids: gas condensates, light oil. <u>Rock Properties</u> 1. Statistical Analysis of rock properties data (porosity, permeability, capillary pressure). Special core analysis experimental methods (capillary pressure, wettability, relative permeability, drainage). 2. The theory of two-phase fluid flow through the porous medium. 3. Analysis of the non-miscible, miscible and diffuse flow.

	4. Calculation, analysis and development of correlations from experimentally determined data. 5. Instantaneous and cumulative rock compressibility coefficient - determination and use in material balance calculations. Fluid Characterization for calculations based on Equation of State (EOS) 1. Characterization of C7 + fractions: statistical distribution of fraction properties, splitting, critical properties, reduction of component number by grouping into pseudocomponents (experimental and mathematical methods). 2. Application of cubic EOS data for phase equilibria calculation. 3. Adjustment of EOS parameters using experimental PVT data. 4. Fluid composition descriptions with respect to the requirements for oil or condensate fluid systems. 5. Enhanced Oil Recovery (EOR) by gas injection processes. 6. Development of a mathematical model of phase behavior using EOS. 7. PVT modeling to determine the minimum miscibility pressure (MMP) for EOR gas injection methods. Gas-Brine Systems 1. Properties of reservoir and geothermal water. 2. Phase equilibrium in the gas - sodium chloride - water system. 3. Gas solubility in water and water in gas. 4. Features of the groundwater phase diagrams and development of EOS for groundwater systems. 5. Determination of an unique EOS for reservoirs with compositional grading. Complex Multiphase Systems 1. Correlations for determining the brine viscosity and the interfacial tension of water-gas system. Characterization of a system with high CO2 content for estimating tertiary methods or permanent storage of CO2 in the underground. 2. Possibility to use EOS for some systems with high CO2 content (CO2-water in geothermal reservoirs). 3. Thermodynamic characterization of the ternary systems of CO2-H2O-NaCl. 4. Thermodynamic characterization for optimization of separation conditions. 5. Gas hydrates: properties, conditions of hydrate creation and importance.
Method of instruction	Teaching will be conducted through lectures (*1 ECTS*), auditory exercises (*2 ECTS*) and laboratory practice (*2 ECTS*). Teaching materials and activities will be on the Merlin e-Learning system. Within the auditory exercises, the students will be able to solve the tasks on a given subject independently and prepare a seminar work and a report based on standards for EOR, PVT and similar laboratory studies. As part of the practical work, students will independently measure, determine, classify and interpret rock and fluid patterns and evaluate the possibility of performing some laboratory-tested processes in the reservoir. The course should result in a study of laboratory results and a seminar or scientific work that confirms or critically considers the methods of interpretation collected through literature research.
Evaluation of student performance	Knowledge verification consists of the following: 4. Practical validation of the *routine* and special rocks analysis measurements (by reporting and interpreting laboratory-measured data). 5. A Practical Approach to Application of the Fluid Performance Interpretation Method (consistency of composition, recombination, PVT table and diagrams)

	6. Students are required to prepare a seminar / scientific work related to the course and present it to the congress or in front of the teacher and the PhD students. 7. The student can choose the analysis area, i.e. analysis parameters, and write a report based on the standard requirements for PVT reports or specialized EOR, PVT and similar laboratory studies.

20-NI07 Course description	
Name of the course	***Oil and Gas Production Optimization (total 4 ECTS)*** ***- teacher: Vladislav Brkić***
Main goals	- Present well test methods and interpret measurement results, - Define the productivity index and future IPR curve, - Define the parameters to optimize the production of reservoir fluids by flowing up and by artificial lift methods and to optimize well completion, - Develop criteria for artificial lift methods optimization by using Nodal analysis of the production system.
Expected learning outcomes (level 8.2)	Upon completion of the learning process the doctoral candidate will be able to: - Propose well test method and interpret measurement results (1 ECTS); - Design a current and future IPR curve (1 ECTS); - Formulate parameters for optimization of well production by selecting the appropriate artificial lift method and appropriate well completion (1 ECTS); - Engineering of well completion and artificial lift method (1 ECTS).
Outlines /module content	- Well testing in order to define the production parameters - The productivity of wells, productivity index, IPR curve, Tubing curve (discharge capacity) - Flowing up method of formation fluids- regulation and production optimization, well completion optimization - Calculation and optimization of artificial lift systems, well completion and control of the production system - Optimization of oil and gas production by using Nodal analysis
Method of instruction	Lectures (1 ECTS), computer exercises (1 ECTS), examples from scientific journals (2 ECTS).
Evaluation of student performance	3. Production optimization tasks by using Nodal analysis. 4. Oral exam.

20-NI08 Course description	
Name of the course	***Oil and natural gas processing transportation and storage (4 ECTS)*** ***- teacher: Simon, K.***
Goals of the course	- present different oil and gas gathering systems - present natural gas processing methods including liquefaction - explain the procedure of selecting an appropriate natural gas processing method - Implement a computer software for natural gas processing or liquefaction optimisation - define oil or gas transportation system - explain the principles for designing oil storage tanks
Expected learning outcomes (levels 8.2)	Upon completion of the learning process the doctoral candidate will be able to: - Design of natural gas gathering systems for delivering natural gas to processing facilities (1 ECTS) - Plan appropriate natural gas processing methods including liquefaction (1,5 ECTS). - Design and optimize various transportations systems used to deliver natural gas Including liquefied natural gas (LNG), compressed natural gas (CNG) and crude oil to end users (1 ECTS) - Design of thecrude oil storage tanks (0,5 ECTS)
Course content	Natural gas processing - separating various impurities from the produced natural gas in order to produce dry natural gas. Processes involved in gas purification include: separation - to remove condensate and free water; dehydration - to remove water vapour; sulphur and carbon dioxide removal; and natural gas liquid extraction. Implementation of software for optimization of different processes such as evaluating gas and liquid sweetening processes for amine absorbents and calculation of H_2S and CO_2 absorption, models of single or blended amine solutions including most commonly selected solvents. Research and optimisation of the most important components of the LNG chain including liquefaction, regasification, storage of liquefied natural gas –as well as distribution and delivery of natural gas through the national natural gas pipeline system and distribution to end users. Oil processing, transportation and storage
Method of instruction	Power Point lectures accompanied by examples with application of appropriate software. Lectures (1 ECTS), Examples and computer exercises (1,5 ECTS), Examples from scientific journals (0,5 ECTS), learning for oral exam (1 ECTS).
Evaluation of student performance	Evaluation of a student's project (case study) through evaluation of software model setting, input data selection, validation and presentation of results; oral exam.

20-NI09 Course description	
Name of the course	***Reservoir engineering of shallow and deep geothermal resources (4 ECTS)*** ***- teacher: Kurevija, T.***
Goals of the course	- demonstrate features of heat transfer conduction and convection in porous media and geothermal reservoirs - define mathematical models of heat transfer in porous media; define analytical and numerical solving of line source and cylindrical source heat transfer - present principles of geothermal reservoir engineering and defining optimal location of production and injection wells - define principles of sustainability and renewability of geothermal energy reservoir exploitation from the view of fluid production
Expected learning outcomes (levels 8.2)	-Formulate processes of heat transfer in porous/convective or conductive media and interconnect it with the sustainability and renewability of geothermal reservoir exploitation (1ECTS) -Solving analytical and numerical mathematical models of heat transfer in convective/conductive environment with application on real geopressured geothermal reservoir (1ECTS) -Planning of geothermal reservoir production-injection system, EGS/HDR system and shallow geothermal borehole heat exchanger grid (1ECTS) -Creating technoeconomical analysis of geothermal reservoir exploitation from the aspect of isotherm period of fluid production (1ECTS)
Course content	Systematic reinterpretation of geothermal potential in Croatia, Geothermal recovery factor (GRF) considering actual technological development, Significance of GRF for different type of reservoir, Convective hydrothermal, geopressurized, conductive dominant and other reservoir types, Porosity and fluid mechanics in pore volume, Reservoir pressure and temperature, Technology of heat transfer from reservoir to the surface, GFR as an indicator of sustainability. Correlation between sustainability and renewability of the geothermal reservoirs: accumulated and renewable energy of the geothermal resources, equations of mass and heat transfer, analytical and numerical solutions, combined analytical-numerical algorithm (Gringarten-Sauty), heat transfer between matrix and pores (Bodvarsson-Tsang), optimization model implementation for injection wells arrangement in reservoirs with intergranular and dual porosity, thermogravimetry phenomena. Thermogeological principle of borehole heat exchanger grid modelling during exploitation of shallow geothermal resources.
Method of instruction	*Lectures (20 hours) + Exercises (5 hours): total 25 hours = 1 ECTS *Examination and research of professional and science papers and studies, collecting of data and preparation of science paper, approximately 400 pages of professional and scientific literature, 40 hours = 1,5 ECTS *Writing of science paper (cca. 10 pages), 40 hours = 1,5 ECTS
Evaluation of student performance	Students are obligated to write seminar paper and presented it to colleagues and to the teacher. Seminar needs to be in a form of science paper which is strongly suggested to publish in the adequate science journal. Final exam consists of oral exam and seminar presentation.

20-NI10 Course description	
Name of the course	***Economics, energy projects management and strategic management (4 ECTS) - teacher: Karasalihović Sedlar, D.***
Goals of the course	• to define investment planning procedures; • to evaluate types of investment projects and recommend methods of their planning and preparations; • to link and evaluate the elements of investment studies; • to analyse financial reports and evaluate investment projects; • to analyse the systems and modelling in project management; • to evaluate the parameters for cost benefit analysis; • to describe business strategies.
Expected learning outcomes (level 8.2)	Economics (2 ECTS): • Analyse market relations; • Determine investment project critical parameters; • Plan the investment project within energy sector; • Prepare the investment project for application of investment evaluation method application; • Carry out static and dynamic evaluation of the investment; • Carry out the cost benefit analysis of the project; • Present the results of investment evaluation and create the final investment decision; Strategic management (2 ECTS): • Carry out the SWOT analysis; • Formulate the business strategy of energy company considering market conditions.
Course content	The subject content includes following teaching units from the defining investment idea through selection of one investment option and making final investment decision in energy projects: • Economic, ecological and social characteristics of energy projects; • Basic financial documents of a company; • Economic characteristics of company business; • Investment policy; • Planning of investment projects; process of investment; • Financing of business, securities, capital market; • Investment documentation, preparation of investment projects; • Market analysis; Technology-technical analysis; Location analysis; Economic-financial analysis; • Market evaluation of the project with the use of static and dynamic methods for investment evaluation necessary for investment decision making; • Business risk management; • Project performance indicators; Financial reporting, financial reports analysis; • Cost benefit analysis (benefits and costs considering investor's interest and social benefits and costs of each action (project); • Investment decision-making; • Business planning and management; • Strategic management; • Legislation in company business and energetics.
Method of instruction	Teaching in form of lectures and exercise. Lectures include power point presentation of the content and exercises based on examples of investment

	projects and business strategies from the industry (independent analysis using software) according to the specialty of the students. Economics (2 ECTS) Strategic planning (2 ECTS) 20 hours of lectures and exercises + 5 hours of seminar papers
Evaluation of student performance	8. Student’s project: Analysis of investment project and formulation of business strategy – *Students are obliged to make a seminar paper, which will include the analysis of investment project and present it in front of the colleagues and teacher.* 9. Oral exam – *Within oral part of the exam student must answer questions regarding the subject matter (curriculum).*

<table>
<tr><th colspan="2">20-NI11 Course description</th></tr>
<tr><td>Name of the course</td><td>Oil and gas markets (4 ECTS)
- teacher: Karasalihović Sedlar, D.</td></tr>
<tr><td>Goals of the course</td><td>• to analyse global, regional and national oil market;
• to define participants at national and regional oil market;
• to analyse global, regional and national gas market;
• to define participants at national and regional gas market;
• to reassess organization and natural gas market management;
• to analyse energy markets regulation;
• to know the methods of economic price regulation and tariff methodology
• to assess the particularities of energy source market, monopolies and influences;
• to evaluate energy production and consumption;
• to asses energy policies and strategies;
• to understand energy source prices trends;
• to evaluate the role of oil in transition towards low-carbon society;
• to evaluate the role of natural gas as transition energy source towards low-carbon society;
• to evaluate geopolitical influences on energy markets.</td></tr>
<tr><td>Expected learning outcomes (level 8.2)</td><td>Oil market (2 ECTS)
• Analyse trends in oil market;
• Asses the relations between participants in national and regional oil market;
• Argue the particularities of oil market;
• Recommend the company's energy policy regarding market conditions;
• Formulate the segment of energy strategy within oil market
• Evaluate the geopolitical role of oil
• Evaluate the level of security of oil supply.

Gas Market (2 ECTS)

• Analyse the trends in gas market;
• Evaluate the relations between parties (participants) in national and regional gas market;
• Present the role of liquefied natural gas and possibility of direct use;
• Argue the particularities of gas market;
• Recommend the company's energy policy regarding market conditions;
• Formulate the energy strategy segment within gas market;
• Evaluate the geopolitical role of natural gas;
• Evaluate the level of security of natural gas supply.</td></tr>
<tr><td>Course content</td><td>Oil market
• Historical trends in energy markets;
• Production, consumption, reserves and oil trade structure;
• Structure, participants and relations in oil market;
• Development of oil market;
• Particularities of oil market, historical monopolies;
• Oil price trends;
• Security of oil supply;</td></tr>
</table>

	• Energy policies and strategies regarding oil; • Legislation in oil market; • Petroleum geopolitics. Gas market • Production, consumption, reserves and gas trade structure; • Structure, participants and relations in gas market; • Gas market development, national model of the market; • Particularities of gas market; • Gas price trends; • Security of natural gas supply; • Energy policies and strategies regarding gas; • Regulation of energy activities; • Legislation in gas market; • Gas geopolitics.
Method of instruction	Teaching in form of lectures and seminar papers. Lectures include power point presentation of the content and within the seminar papers, segments of market, relations and trends (independent analysis) will be observed according to students' specialities. Oil market (2 ECTS) Gas market (2 ECTS) 20 hours of lectures + 5 hours of seminar papers
Evaluation of student performance	10. Student project: Analysis of oil or gas market segment – *Students are obliged to make a seminar paper, which will include analysis of oil or gas market segments and present it in front of colleagues and teacher.* 11. Oral exam – *Within oral part of the exam student must answer questions regarding the subject matter (curriculum).*