University of Zagreb

University of Zagreb FACULTY OF MINING, GEOLOGY AND PETROLEUM ENGINEERING

INTER RGN

1. GENERAL INFORMATION			
1.1. Course teacher	Associate Professor Domagoj Vulin, PhD	1.6. Year of the study	I.
1.2. Name of the course	Multiphase flow in porous rock	1.7. ECTS credits	6,5
1.3. Associate teachers	-	1.8. Type of instruction (number of hours L + E + S + e-learning)	33L+0E+15S+12e-learning
1.4. Study programme (undergraduate, graduate, integrated)	graduate	1.9. Expected enrolment in the course	30
1.5. Status of the course	☒ mandatory ☐ elective	1.10. Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	level 3, 20% online
2. COUSE DESCRIPTION			
2.1. Course objectives	By taking the exam, the student will be able to mathematically describe the multiphase flow in the reservoir rock. Students will use modern methods of upscaling of data from the micro scale to the level of the core and to the level of well data and reservoirs.		
2.2. Enrolment requirements and/or entry competences required for the course	-		
2.3. Learning outcomes at the level of the programme to which the course contributes	Independently solve complex engineering problems in petroleum engineering and geoenergy engineering; Analyse reservoir rock and reservoir fluids properties; Predict reservoir behaviour and the behaviour of hydrocarbon and geothermal water production system.		
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	Describe mathematically physical properties of fluid flow in a porous rock and flow calculations depending on different cases of fluid flow in a porous rock; Match the laboratory and well-logging data; Formulate the data needed for waterflooding calculations and other fluid injection; Formulate the inputs for reservoir simulation models.		

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2.5. Course content (syllabus)	Flow equations; Darcy, Darcy-Weisbach and Forcheimer equations; Examples of flow calculations in linear geometry (Darcy eq.); Examples of flow calculations in radial geometry (Darcy eq.); Example of application of the equation of conservation of mass and continuity to Darcy's flow case; Description of the nonlinear flow in the near-wellbore zone (non-Darcy flow); Algebraic form of a nonlinear relationship between pressure drop and flow rate; Principles for determining zones completely saturated with water and zones partially saturated with water from electric well-logging data; Wettability, capillary pressure, relative permeability; Analytical expression for capillary pressure; Capillary effects on fluid flow. Bundle of tubes concept, effects of different pore geometries on capillary forces. Poiseuille equation; Buckley-Leverett (BL) theory. Basic assumptions and application. Method for determining average saturation; Welge - graphical interpretation of the fractional flow curve; Numerical description of BL calculation of injection fluid front advance in time; Extension of the calculation of flooding by BL method, gravitational term in the calculation (inclined layer), calculation of the required amount of water for injection to a certain extraction; Diffuse flow - Koval's theory; Effects at the pore level - analysis of flow properties at the pore level; Flow of non-Newtonian fluids in a reservoir; Application of fractional flow curve for EOR estimates; Formation compressibility. Stresses in the reservoir rock, and in the laboratory when measuring rock properties; Correlations of mechanical properties of the formation - compressibility, fracture pressure, description of the change in permeability and porosity due to the change of pressure in the reservoir (rock sample); Review of flow equations in differential form. Rock compressibility - an overview of the main parameters related to the mechanical properties of rock, basic equations and applications in reservoir engineering; Rock compressibility - pore compressibility; Analytical tasks - correction of stock estimate based on change in pore volume by pressure reduction; Permeability calculations - Linear and radial flow of incompressible and weakly compressible fluid (water, oil); Permeability calculations II - Linear and radial flow of compressible fluid (gas); Permeability calculations III - Permeability and flow calculations in a segmented heterogeneous model - series of permeability changes, permeability anisotropy in parallel layers; Determination of porosity at the reservoir level - data upscaling from core-level and well-level to the level of the production/injection formation (reservoir); Reservoir permeability assessment - data upscaling from core-level and well-level to the level of the production/injection formation (reservoir); Determination of a representative capillary pressure and saturation curve above the oil-water contact; Statistical methods for processing capillary pressures - Leverett's J (Sw) function; Statistical processing of capillary pressure data using the cross-plot method; Electrical resistance (estimates of porosity and saturation based on resistance data, ie formation factors); Acoustic properties of rock and interpretation of acoustic measurements in the laboratory; Example of numerical calculation of flow in rock; Program task: Multiphase calculations - Calculation of relative permeability from given laboratory results of multiphase flow, calculation of relative permeability ratios based on laboratory data of multiphase flow and Welge method; Program task: Calculation of multiphase immiscible flow (flooding) according to Buckley-Leverett theory.		
2.6. Format of instruction:	☒ lectures ☒ seminars and workshops ☒ exercises ☐ online in entirety ☒ partial e-learning ☒ field work	☒ independent assignments ☒ multimedia and the internet ☐ laboratory ☒ work with mentor ☐ (other)	2.7. Comments: -

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2.8. Student responsibilities	The student should submit calculations in the prescribed seminar format, making clear the difference between individual work and teamwork.

2.9. Monitoring student work	Class attendance	YES		Research		NO	Oral exam	YES	
	Experimental work		NO	Report		NO			
	Essay		NO	Seminar paper	YES				
	Preliminary exam	YES		Practical work	YES				
	Project	YES		Written exam		NO	ECTS credits (total)	6,5	

2.8. Required literature (available in the library and/or via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	Zimmerman, R.W. (2018.): *Fluid flow in porous media*. World Scientific Publishing Europe Limited.	NO	YES
	Vulin, D. (2020.): Script for the course "Multiphase flow in porous rock*", RGN Faculty, Department of Petroleum and Gas Engineering and Energy.*	YES	YES

2.11. Optional literature	Buckley, S.E., Leverett, M. (1942.): *Mechanism of fluid displacement in sands*, Transactions of the AIME, 146(01), 107-116.
	Koval, E.J. (1963.): *A method for predicting the performance of unstable miscible displacement in heterogeneous media*, Society of Petroleum Engineers Journal, 3(02), 145-154.
	Brooks, R.H., Corey, A. T. (1964): *Hydraulic properties of porous media*, Hydrology papers (Colorado State University); no. 3.
2.12. Other (as the proposer wishes to add)	-

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