1. GENERAL INFORMATION				
1.1. Course teacher	Associate Professor Tomislav Kurevija, PhD		1.6. Year of the study	II.
1.2. Name of the course	Applied thermogeology and shallow geothermal potential		1.7. ECTS credits	4
1.3. Associate teachers	Teaching Assistant Marija Macenić, PhD		1.8. Type of instruction (number of hours L + E + S + e-learning)	45L+0E+10S+5e-learning
1.4. Study programme (undergraduate, graduate, integrated)	graduate		1.9. Expected enrolment in the course	15
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 2, 8,3% online
2. COUSE DESCRIPTION				
2.1. Course objectives	Students will be introduced to a relatively new term of thermogeology and therefore will be able to understand the principles of designing ground heat exchangers in order to use low enthalpy geothermal resource and heat pumps as part of the thermotechnical system. Also, students will be able to evaluate impact of specific thermogeological parameters, such as thermal conductivity, thermal diffusivity, density, moisture and ground/rock permeability, on system (borehole heat exchanger or very shallow heat exchanger) design. During the course, the students will be able to perform practical measuring of thermal conductivity and undisturbed ground temperature on coaxial borehole heat exchanger installed on the Faculty premises, according to ASHRAE method and using thermal response test apparatus.			
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; Design wellbore for hydrocarbon and geothermal water exploitation; Analyse reservoir rock and reservoir fluids properties; Compare specific procedures and processes in petroleum engineering and geoenergy engineering; Appraise process and facility's efficiency in petroleum engineering and geoenergy engineering; Assess the environmental impact of petroleum engineering and geoenergy engineering.			

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<table>
<tr><td>2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)</td><td colspan="3">Formulate thermodynamic laws of conductive heat transfer;
Assess influence of thermogeological parameters on shallow geothermal energy exploitation;
Design geothermal borehole heat exchangers field, up to few hundred meters in depth, recommend drilling method and grout type, based on thermogeological data (thermal conductivity, borehole thermal resistance, etc.);
Analyse impact of hydrogeological, geological and climate parameters on heat exchanger efficiency;
Evaluate thermogeological energy potential of a given location by analysing thermal response test data;
Elaborate working principles of a heat pump, with ground as a thermal source, describe mechanical elements, evaluate coefficient of performance;
Evaluate required borehole heat exchanger length using analytical methods.</td></tr>
<tr><td>2.5. Course content (syllabus)</td><td colspan="3">Introduction to applied thermogeology, course overview; Deep and shallow geothermal energy; Direct and indirect utilization of thermal energy; Shallow geothermal energy potential and definitions of fundamental parameters; Fundamental thermodynamic and technological characteristics of heat pumps with ground and groundwater as a heat source; Overview of equipment and technology; Ground source heat pump working modes as a necessary asset to utilize low enthalpy geothermal potential; Theoretical fundamentals of modelling borehole heat exchangers as a low enthalpy geothermal source for heat pump; Defining the working cycle of the ground source heat pump, calculations of fundamental parameters in TS diagram; Analytical solution to cylindrical heat transfer model; Analytical solution to line source heat transfer model; Calculations of fundamental thermogeological and physical variables of source rock and fluid necessary for heat pump; Kavanaugh’s numerical model for temperature distribution surrounding the borehole, based on solution to cylindrical heat transfer; Eskilson’s numerical model for long-term temperature response of the borehole heat exchanger; Graphoanalytical analysis of undisturbed ground temperature and its depth; Defining fundamental input parameters necessary for evaluating shallow geothermal potential; Modelling borehole heat exchanger field using RETScreen program; Modelling borehole heat exchanger field as a function of specific input parameters, Modelling borehole heat exchanger field using GLD and GHX programs; Measuring thermal conductivity using thermal response test (TRT) apparatus on inclined coaxial borehole heat exchanger, located on Faculty premises; Calculation and analysis of thermal conductivity obtained via thermal response test; Modelling of inclined coaxial borehole heat exchangers based on known thermogeological parameters; Analysis of data obtained via TR test and step TR test – evaluating borehole thermal resistance, skin factor and extraction rates; Modelling very shallow geothermal heat exchangers, up to 2 m in depth; Using ground stored solar energy; Overview of available technology and techniques of installation; Technoeconomical analysis of cost effectiveness of using ground and groundwater heat pump; Overview of energy sources, calorific values, pricing and energy savings; Reducing CO_2 by using ground source or groundwater source heat pumps compared to conventional energy systems; Comparison in RETScreen program.</td></tr>
<tr><td rowspan="2">2.6. Format of instruction:</td><td rowspan="2">☒ lectures
☒ seminars and workshops
☐ exercises
☐ online in entirety</td><td rowspan="2">☒ independent assignments
☒ multimedia and the internet
☐ laboratory</td><td>2.7. Comments:</td></tr>
<tr><td>-</td></tr>
</table>

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	☒ partial e-learning ☐ field work	☒ work with mentor ☐ (other)	
2.8. Student responsibilities	Active participation in lecture, preparation and presentation of the seminar paper, taking the oral exam.		

2.9. Monitoring student work								
	Class attendance	YES		Research	YES		Oral exam	YES
	Experimental work		NO	Report		NO		
	Essay		NO	Seminar paper	YES			
	Preliminary exam		NO	Practical work		NO		
	Project	YES		Written exam		NO	ECTS credits (total)	4

2.10. Required literature (available in the library and/or via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	Banks, D. (2008.) *An introduction to thermogeology: ground source heating and Cooling*, Blackwell, Oxford, 339 pp.	NO	YES
	Kavanaugh, S.P., Rafferty, K. (1997.): *Groundsource Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings*, American Society of Heating, Refrigeration and Airconditioning Engineers, Inc., Atlanta, GA.	NO	YES
	Chiasson, A. (2016.): *Geothermal Heat Pump and Heat Engine Systems Theory And Practice*, Wiley.	NO	YES

2.11. Optional literature	Egg, J. (2010.): *Geothermal*, HVAC McGraw Hill Professional pp 272.
	Ingersoll, L.R., Zobel, O.J., Ingersoll, A.C. (1954.): *Heat Conduction with Engineering, Geological and Other Applications*, Madison, WI: The University of Wisconsin Press.
2.12. Other (as the proposer wishes to add)	-

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