UNIVERSITY OF MISKOLC

FACULTY OF
EARTH AND ENVIRONMENTAL
SCIENCES AND ENGINEERING

Geothermal Energy

MFKGT740011

MSc in Petroleum Engineering

full time course

SUBJECT-MATTER COMMUNICATIONS DOSSIER

UNIVERSITY OF MISKOLC
FACULTY OF EARTH AND ENVIRONMENTAL SCIENCES
AND ENGINEERING
INSTITUTE MINING AND ENERGY

Miskolc, 2023/2024. academic year I. semester

CONTENT

SUBJECTS DATA SHEET

Course Title: Geothermal energy **Instructor:** Dr. Anikó Nóra TÓTH, Honorary professor	**Code:** MFKGT740011 **Responsible department/institute:** BEI **Compulsory/Elective: C**
Position in curriculum* **(which semester)**: 1 (4)	**Pre-requisites (if any):** no
No. of contact hours per week (lecture + seminar): 2+0+1	**Type of Assessment (examination / practical mark / other):** practical mark
Credits: 3	**Course:** full time

Course Description:

This is a graduate course covering the natural conditions, production and utilization, environmental impact of geothermal energy. The purpose of this course is to provide you with a broad understanding of these topics and their history, which will prove useful in other courses, your individual research, reading of the literature, and engineering practice. Information in this class can be applied prospecting and design of geothermal production technology and equipment together with the surface facilities of utilization. We will rely primarily on lectures and teamwork to develop your understanding of these principles. You will be expected to read and think about material outside class, and to take part actively in class discussions. These discussions will enhance the learning process, allow sharing of experiences, and hopefully make this course more interesting.

Competencies to evolve:

Knowledge: T1, T11

T1 Knows the economic processes related to the hydrocarbon industry.

T11 Familiar with the methods and software of computer design and analysis in the hydrocarbon industry.

Ability: K1, K5, K6, K7, K8, K9, K10, K11

K1 Able to interpret the economic processes related to the hydrocarbon industry and give adequate answers to them.

K5 Capable of selecting the optimum production method, designing and selecting the production equipment.

K6 Capable of forecasting the behavior of the fluids found in the petroleum, natural gas and geothermal reservoirs, the properties of the reservoir rocks and the characteristics of the seepage in the reservoirs.

K7 Able to recognize the production mechanisms of underground reservoirs and to select the optimum of primary or enhanced recovery mechanisms.

K8 Able to perform a numerical simulation of underground reservoirs.

K9 Capable of monitoring and checking equipment related to the transport of oil, gas and water through pipelines.

K10 Capable of selecting equipment for field and transfer line delivery of fluids and supervising equipment operation and managing the groups involved.

K11 Capable to perform computer design and evaluations for hydrocarbon industry.

Attitude:-A1, A2, A3, A4

A1 Enforce sustainability and energy efficiency requirements.

A2 Strive professionally at a high level, independently or in a workgroup to plan and carry out tasks.

A3 Strives to carry out work using a complex approach based on a systematic and process-oriented mindset.

A4 Seeks to achieve research, development and innovation goals during work.

Autonomy and responsibility: F6, F7

F6 Has an autonomous capacity to plan the use of renewable natural resources and from residues into the energy supply system, to operate the established system

F7 Takes responsibility for professional decisions, for carrying out workflows or managing them.

Assessment and grading:

Students will be assessed with using the following elements.

Attendance:	5 %
Homework	10 %
Midterm exam	40 %
Final exam	45 %
Total	100%

Grading scale:

% value	Grade
90 -100%	5 (excellent)
80 – 89%	4 (good)
70 - 79%	3 (satisfactory)
60 - 69%	2 (pass)
0 - 59%	1 (failed)

Compulsory or recommended literature resources:

A. Toth and E. Bobok: Flow and Heat Transfer in Geothermal Systems, Elsevier, Amsterdam, London, New York, Tokyo, 2016, ISBN: 9780128002773, 2016.

A. Toth: Geothermal Direct Uses, Digital lecture notes, 2014. http://www.tankonyvtar.hu/hu/

A. Toth: Heat Pumps, Digital lecture notes, University of Miskolc, 2014. http://www.tankonyvtar.hu/hu/

J.W. Lund: Geothermal Direct-Use Engineering and Design Guidebook. Geo-Heat Center

R. Horne: Modern Well Test Analysis: A Computer-Aided Approach. Petroway, Inc., 1995, ISBN 0-9626992-1-7.

Ronald DiPippo: Geothermal Power Plants, Elsevier, 2013, ISBN: 978-0-08-098206-9

COURSE SCHEDULE

Date	Week	Topic
2023.09.15.	1.	Geothermal energy phenomena
2023.09.22.	2.	Geothermal reservoirs
2023.09.29.	3.	Geothermal heat flow
2023.10.06.	4.	Simple analytical reservoir models
2023.10.13	5.	Geothermal drilling practice
2023.10.20	6.	Well test analysis
2023.10.27.	7.	Test writing Heat transfer in geothermal wells
2023.11.03.	8.	Educational break
2023.11.10.	9.	Production from a geothermal well
2023.11.17.	10.	Steam and hot water transmission by pipe-line
2023.11.24.	11.	Direct application. EGS system
2023.12.01.	12.	Sustainability and depletion
2023.12.08.	13.	Geothermal heat pump. Environmental effects
2023.12.15.	14.	Test writing

Test Sample

University of Miskolc
Department of Natural Gas Engineering
H3515 Miskolc – Egyetemváros
Phone: +36 46 565 078
E-mail: gastitkar@kfgi.uni-miskolc.hu
Web: www.gas.uni-miskolc.hu

0-59 % (failed)
60-69 % (pass)
70-79 % (satisfactory)
80-89 % (good)
90-100 % (excellent)

NAME:……………………………………

TEST FOR GEOTHERMAL ENERGY

1. What is a geothermal reservoir? How can we distinguish between different types of geothermal reservoir?
2. What does geothermal filed means?
3. Give examples of different types of geothermal reservoirs exploitation!
4. What does Enhanced Geothermal System mean? How does it work?
5. Let's assume a two-layers formation - 1000 m of sediments, above 500 m of basalt. The mean annual surface temperature is 5°C. A 200 m temperature-gradient hole has been drilled, where the bottom-hole temperature is 45°C. The surface temperature is 7°C.

   a) What is the geothermal gradient in the hole?
   b) What is the terrestrial heat flow?
   c) What is the temperature at the bottom of the sediment layer, at the bottom of the clay layer and at the bottom of the basalt layer?
   The thermal conductivity for each of the three layers:
   sediment *1.67 W/mK*
   basalt *2.51 W/mK*

TEST SAMPLE ANSWER

1. What is a geothermal reservoir? How can we distinguish between different types of geothermal reservoir?

A geothermal reservoir is a volume of rocks in the subsurface which exploitation in terms of heat can be economically profitable.

The temperature of the fluid and the possible applications are important to sort reservoirs. Thus, four types of geothermal reservoirs can be defined:

High temperature: These reservoirs provide enough heat to make electricity from steam profitably. High temperature reservoirs are generally more than 150° C, and are located in areas of thin lithospheric thinness or active volcanism.

Within the group of high-temperature geothermal reservoirs there are "Hot Dry Rock" (HDR) geothermal reservoirs, which are exploited by the techniques called "stimulation of geothermal reservoirs" (EGS: Enhanced Geothermal System). They consist of fracturing a mass of deep rock to create a geothermal reservoir allowing the circulation of fluids inside it. These reservoirs not require high thermal gradients, but a very specific geological context. Although the implementation of such reservoir is still experimental (i.e. Soultz-sous-Fôrets, in France) in Catalonia have been granted some exploration permits.

Middle temperature: Despite these reservoirs have a lower temperature compared to the high temperature ones, they allow extracting sufficient heat to produce electricity (but with lower performances) using a volatile fluid. The reservoirs usually reach temperatures between 100 and 150º C, and are located in areas with favorable structural and geological contexts and geothermal gradients higher than the average. Their direct use may be in heating mode and their main applications are in district heating systems and industrial processes.

Low temperature: The temperature of these reservoirs is between 100 and 30° C. They are located in areas with a favorable geological context including deep aquifers; the geothermal gradient is like the average in the region. Their exploitation involves pumping hot groundwater from the aquifer and re-injecting it after it has delivered the heat and is cold again. These are used in direct applications and for district heating systems and industrial processes.

Very low temperature: The temperature of these reservoirs is below 30° C. In these, the underground is used as a heat exchanger, by means of a heat pump in a closed circuit. Their applications are in domestic and agricultural air conditioning systems. These kinds of reservoirs may be anywhere, because their efficiency is just determined by the underground thermal inertia in normal (average) geothermal gradient conditions.

2. **What does geothermal filed means?**

The Geothermal Field is a geographical notion. Geothermal fields are regions in the Earth where we see surface manifestations, e.g., geysers, boiling mud ponds, and fumaroles, which indicate an active geothermal domain underground.

3. Give examples of different types of geothermal reservoirs exploitation.

a) **High temperature:** In a deep granitic basement beneath a sedimentary cover (ratio units with a thermal conductivity contrast promotes the geothermal gradient), cold water is injected and hot water is extracted in such a way that in contact with a second surface circuit, it generates hot steam for electricity production.

b) **Middle temperature:** Hot groundwater is drawn from a deep aquifer to exchange heat within an urban district heating system, and cold water is re-injected.
c) **Very low temperature:** Ground thermal inertia is exploited through a buried heat exchanger that provides a stable fluid temperature to heat a house in winter and cold it in summer.
d) **Thermal spring:** It is also represented on the picture a natural thermal convection half-cell caused by a groundwater circulation process: Infiltration in a recharge zone, a slow transition through a deep aquifer, quickly draining to the surface through a permeable fault giving way to a thermal spring.

4. What does Enhanced Geothermal System mean?

An Enhanced Geothermal System (EGS) is a man-made reservoir, created where there is hot rock but insufficient or little natural permeability or fluid saturation. In an EGS, fluid is injected into the subsurface under carefully controlled conditions, which cause pre-existing fractures to re-open, creating permeability.

Huge regions of the earth's crust are very hot, but have neither a permeable rock matrix nor any geofluid. In these case artificial geothermal reservoirs can be created. The necessary interconnecting fracture system can be produced by hydraulic fracturing, a routine technology in the petroleum industry. To create such a system, the first step is to drill a sufficiently deep, mainly inclined well into the chosen part of the hot dry rock. Once the designed depth is reached, the so-called fracturing fluid is injected under very high pressure.

How does it work?

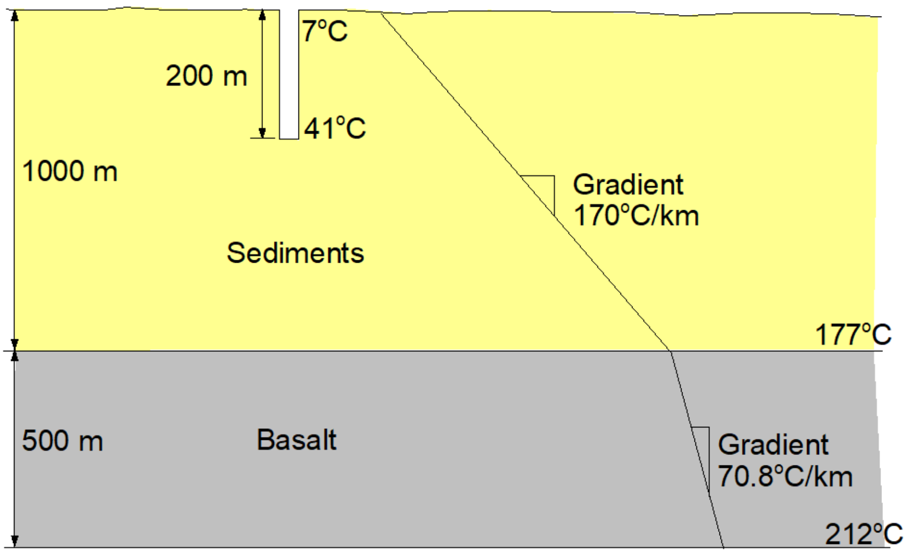
The fracturing fluid is a two-phase fluid-solid mixture, containing solid particles, the so-called proppants. As the fracturing fluid is pumped into the opening, crack proppants spread over the fracture surfaces. The crack remains open until the pump produces the necessary high pressure. When the pump stops, the pressure of the fracturing fluid decreases to the hydrostatic pressure level.

5. What's the temperature beneath the basalt?

Two layer formation: 1000 m of sediments over 500 m of basalt
Drill down to 200 m in the temperature gradient hole, where bottom hole temperature = 41ºC
Mean annual surface temperature = 7ºC

a) Temperature gradient in hole (assuming a conductive gradient)=(41-7ºC)/0.2km =170ºC/km
Temperature at bottom of sediments = 170ºC/km x 1.0 km + 7ºC = 177ºC
Based on experience, assume the basalt's thermal conductivity is 2.5 times that of the sediment (1.67 vs 4.18 W/m K)
So, assuming the heat flow is the same as the heat flow from the sediment layer:
$q = r \times k = 0.170ºC/m \times 1.67 W/m\,K = 0.284 W/m^2$

b) We know the basalt's temperature gradient is:
$r = q/k = 0.284 W/m^2 / 4.18 W/m\,K = 0.0679ºC/m = 67.9ºC/km$
Thus the temperature below the basalt is:
= 177ºC + 0.0679ºC/m x 500 m = 177 + 35 = 211ºC = 412ºF (very good!!!)


7°C
200 m
41°C
1000 m
Gradient
170°C/km
Sediments
177°C
500 m
Basalt
Gradient
70.8°C/km
212°C

COURSE TOPICS TO BE PREPARED TO THE EXAM

1. ***Introduction to Geothermal Energy***
   i. What is geothermal energy
   ii. Historical background
   iii. Review of the geothermal activities worldwide
2. ***Geological Background***
   i. Origin of geothermal energy
   ii. Terrestrial heat flow, geothermal gradient
   iii. Relationship of plate tectonics and terrestrial heat flow
   iv. Geothermal field
   v. Geothermal reservoir
3. ***Types of Geothermal Reservoirs***
   a. High, medium and low enthalpy reservoirs
   b. Fractured reservoirs
   c. Porous reservoirs
4. ***The Geothermal System***
   a. Elements of the geothermal systems
   b. Behavior a geothermal system
   c. Utilization
5. ***Flow and Heat Transfer in Geothermal Systems***
   a. Flow an heat transfer in production wells
   b. Heat exchangers
   c. Flow an heat transfer in injection wells
6. ***Geothermal Energy Utilization***
   a. Geothermal power plants
      i. Dry steam power plants – Examples
      ii. Flash steam power plants – Examples
      iii. Binary power plants
      iv. EGS Fenton Hill, Los Alamos (USA), Soultz-sous Forets (France)
   b. Geothermal direct uses
      i. District heating – Examples
      ii. Agriculture, Greenhouse and Covered Ground Heating– Examples
      iii. Aquaculture Pond and Raceway Heating – Examples
      iv. Agricultural Crop Drying – Examples
      v. Industrial Process Heat – Examples
   c. Balneology, Bathing and Swimming – Examples
7. ***Environmental Impact***