EME 497 – GEOTHERMAL ENERGY ENGINEERING
SYLLABUS

Lecture: TuTh 12:05-01:20 (Blended course: both in-class and online)
Location: 102 Leonhard Bldg.
Resource Page: https://personal.ems.psu.edu/~fkd/courses/eme_497/index.html
Texts: Selected texts on reserve in EMS Library and on `canvas.psu.edu`.[1]
Instructor(s): *Aagje Eijsink* 230A Hosler eijsink@psu.edu
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Prerequisites: None, but understanding of EME 301 & 303, recommended.
Grading:

Select pre-existing student-created videos	20%
Participation – pre-recorded lectures & quizzes	40%
Individual 20 min presentations on topical area(s)	30%
Comprehension of student videos – online quizzes	10%
Total	100%

Topic		**Sub-Topic**	**Reading**[1]	**Week**
1. Introduction		Overview; scientific challenges; economic perspective, development of geothermal reservoir engineering.	WG1 + AG1	#1
2. Thermal Characteristics				
2:1	Sources of Geothermal Heat	Origins of heat, heat transfer, geological environments, reservoir systems – conductive, convective-liquid-dominated and convective-vapor-dominated, reservoir evolution.	WG2 + AG2	#2
2:2	Thermodynamics	First law, second law, Gibbs function and Energy, Efficiency.	WG3	#3
3. Fluid Flow and Geochemistry				
3:1	Subsurface Fluid Flow	Porosity and permeability, porous and fractured reservoirs, head and pressure, storage, properties of real geothermal reservoirs.	WG4	#4
3:2	Simple Quantitative Models	Concepts of storage, pressure transient models, lumped parameter models, steam reservoir with immobile water, reserves, fractured media.	AG2-3	#5
3:3	Chemistry of Geothermal Fluids	Geochemistry of geothermal fluids, chemical systems, saturation and law of mass action, kinetics, gases in geothermal fluids, fluid flow and mixing, modeling.	WG5	#6
4. Resource Exploration and Characterization		Geology (WG6), geophysics (WG7), resource assessment (WG8), drilling (WG9), interpretation of downhole measurements (AG4), downhole measurements (AG5), measurements during drilling (AG6), well completion (AG7), production testing (AG8).	WG6-9 + AG4-8	#7+#8
5. Geothermal Energy Recovery and Conversion				
5:1	Geothermal Power – Hydrothermal	History of production, dry steam resources, hydrothermal systems, binary generation facilities.	WG10	#9
5:2	Geothermal Power – SedHeat	Key issues in SedHeat and EGS, behaviors, fluid flow and heat transport modes, utilization of O&G technologies. https://youtu.be/8wOTesyA66c		#10
5:3	Geothermal Power – EGS	Concept, resource size, characteristics, methods of stimulation and permeability evolution, history. Reservoir management and sustainability. https://youtu.be/EzeE0DlarUg	WG13	#11
5:4	Direct Use	Reservoir assessment, modes of heat transfer, establishing feasibility, district heating, aquaculture, drying.	WG12	#12
5:5	Low Temperature Geothermal – GSHP	Basic principles, thermodynamics, shallow subsurface thermal reservoirs, thermal storage and thermal transport in soils, design.	WG11 + MR5+6	#13
5:6	Underground Thermal Storage	Principles, conductive and convective transport, chromatographic effect, multi-well and huff-n-puff systems.	MR4	#14

References[1]/Resources:

1. Grant, M.A. and Bixley, P.F. Geothermal Reservoir Engineering. Second Edition. Elsevier. 2011. [AG]
2. Glassley, W.E. Geothermal Energy. Second Edition. CRC Press. 2015. [WG]
3. Rosen, M.A. and Koohi-Fayegh, S. Geothermal Energy. Sustainable Heating and Cooling Using the Ground. 2017. [MR]
4. Penrose SedHEAT: https://www.youtube.com/channel/UCBHQHy4hVyBJQFogrKvKUAg
5. Great Lakes SedHEAT: https://igws.indiana.edu/glsn/speakers

Course Conduct:
Penn State's policy on academic integrity applies to all aspects of course deliverables. Students are encouraged to work together on all assignments but must submit independent work for all graded deliverables and exams. Further details are available for academic integrity and code of conduct at:
https://www.ems.psu.edu/undergraduate/academic-advising/policies-procedures-and-forms/academic-integrity-undergraduates

~~Per *AD 42-27* class attendance for this course is encouraged. "A student should attend every class for which the student is scheduled and should be held responsible for all work covered in the courses taken."~~ Reasons for late deliverables should be appropriately corroborated (e.g. doctor's note, etc.).

This syllabus may be updated during the semester and you will be responsible for abiding with any such changes.

Additional generic Penn State policies that apply to this course are at:
https://www.ems.psu.edu/~elsworth/courses/eme_303/outline_add.docx

Grade Divisions: A (>93.3%); A- (>90.0%), B+ (>86.6%); B (>83.3%); B- (>80.0%), C+ (>75.0%); C (>70.0%), D (>60.0%); F (<60.0%)

Spring 2023 Calendar – At-a-Glance [In-class and Online]

January 2023

Su	Mo	Tu	We	Th	Fr	Sa	Wk	Deliv	Tuesday	Thursday	
8	9	10	11	12	13	14	1	I-c	0. Organizational Meeting	1. Introduction	
15	16	17	18	19	20	21	2	O-A	2.1 Sources of Geothermal Heat		
22	23	24	25	26	27	28	3	O-A	2.2 Thermodynamics of Geothermal Reservoirs		
○	30	31									

February 2023

Su	Mo	Tu	We	Th	Fr	Sa					
			1	2	3	4	4	O-A	3.1 Subsurface Fluid Flow		
5	6	7	8	9	10	11	5	O-A	3.2 Simple Quantitative Models		[JP]
○	13	14	15	16	17	18	6	O-A	3.3 Chemistry of Geothermal Fluids		
19	20	21	22	23	24	25	7	O-A	4.1 Resour. Exp. & Charac. – Geology/Geophysics		
○	27	28									

March 2023

Su	Mo	Tu	We	Th	Fr	Sa					
			1	2	3	4	8	O-A	4.2 Resour. Exp. & Charac. – Drilling/completion		[WP]
~~5~~	~~6~~	~~7~~	~~8~~	~~9~~	~~10~~	~~11~~					
12	13	14	15	16	17	18	9	O-A	5.1 Hydrothermal Systems		[JF]/[GB]
○	20	21	22	23	24	25	10	O-A	5.2 Sedimentary Geothermal Reservoirs		
26	27	28	29	30	31		11	O-A	5.3 EGS		[JM]

April 2023

Su	Mo	Tu	We	Th	Fr	Sa					
						1					
○	3	4	5	6	7	8	12	O-A	5.4 Direct Use		[PF]
9	10	11	12	13	14	15	13	O-A	5.5 Low Temp. – Heat Pumps		
16	17	18	19	20	21	22	14	O-A	5.6 Underground Thermal Storage		[SG]
23	24	25	26	27	28	29	15	O-A	6. 2022 Video Viewing and Quizzes		

May 2023

Su	Mo	Tu	We	Th	Fr	Sa
~~30~~	~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~6~~

○ Assignment submissions

***Class modalities**

I-c	In-class or alternatively completed asynchronously online and verified by quiz
O-S	Online-Synchronous – no In-class meeting but simultaneous zoom broadcast
O-A	Online-Asynchronous – no In-class meeting/no zoom broadcast but recorded lecture verified by quiz

INDIVIDUAL PRESENTATION RUBRIC

In this class, you will develop instructional materials to cover topical areas selected from the syllabus. Each student will be responsible for a single individual presentation on a topical area of their choice. These will be prepared as powerpoint or pdf presentations that follow a loosely-prescribed outline which are then recorded by the students and uploaded online as a tutorial. The narrated recording must be >20 minutes long.

The objectives of this are to: (i) encourage students to explore and to think critically and creatively about a particular topical area, (ii) to understand this area in sufficient depth to communicate and share this understanding with a student audience as a tutorial, and (iii) to learn from the other student tutorials that cover a broad range of topics in the course outline.

Schedule:	**Deliverables**
Week 0 – Organization	
Week 3 – Select a topical area and assemble review materials	[Submit title Su after wk# 3]
Week 5 – Prepare presentation plan/outline	[Submit outline Su after wk#5]
Week 7 – Prepare presentation	[Submit ppt/pdf Su after wk#7]
Week 9 – Narrate ppt/pdf and upload	[Upload video Su after wk#9]
Week 11 – Prepare quiz questions to narration on `canvas.psu.edu`	[Submit questions Su after wk#11]
Weeks 13-15 – Students complete online class material from all other students	[Take other quizzes]

Students will work individually to develop powerpoint or pdf (projected) presentations to communicate the principles of the prescribed topics(s) to this class. The presentations may be ppt presentations (slide show mode) or use screen capture to record the material and will be posted and available to the other students.

The full suite of topical areas are as prescribed in the syllabus with baseline initial and structured resource materials also given in the form of three principal resource texts. These resources will be supplemented by the participants from any available auxiliary resources.

Presentations should include some description of:

1. **Motivation [10%]** Provide context for the topic. *Use of relevant public domain videos* are a useful method for this. Why is this particular topic or sub-topic important in the broad view of geothermal energy engineering?
2. **Scientific Questions to be Answered/Outline [10%]** What questions arise from the motivation. What are the sub-topical areas that address these scientific questions.
3. **For Each Sub-Topic:**
    a. **Detailed Explanation of the Topic [40%]** Describe the physical principles in detail and at a pace that is tutorial for an audience.
    b. **Example Hand-Calculation [10%]** Simple calculation to demonstrate the technique.
    c. **Case Study [10%]** If appropriate.
4. **Conclusion [20%]** Summarize important/key points from the presentation.

OBS Studio may be of interest to you in recording your materials to .m4v format: `https://obsproject.com`

But the easiest way is to follow the **"PPT-to-Movie"** demonstration on the course homepage.

Grading:

To be based on the quality and content of the topical self-presentations and on comprehension of the complementary presentations. Grades to be based broadly on the scoring rubric above.

Sample Quiz Question:

1. Power recovered from sensible heat from a geothermal reservoir/well may be define as
    a. Power = Mass rate of flow * specific heat capacity * temperature change
    b. Power = Mass rate of flow * elevation change
    c. Power = Enthalpy
    d. Power = Entropy * temperature change
2. Question 2……etc.
    a. Answers to Q2