220283 - Renewable Energy

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 724 - MMT - Department of Heat Engines
Academic year: 2019
Degree: MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 7,5
Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: ASENSIO OLIVA LLENA
Others: IVETTE MARIA RODRIGUEZ PEREZ - YOLANDA CALVENTUS SOLE - JESUS CASTRO GONZALEZ

Prior skills
Fundamentals of thermodynamics, fluid mechanics and heat transfer are required to understand how do the systems studied in the course work.

Requirements
Knowledge equivalent to the successful completion of the leveling course of the master

Degree competences to which the subject contributes

Specific:
1. Knowledge and ability to analyze the processes of heat transfer that allows the design and calculation of equipment and thermal applications.
2. Knowledge and capability to design and calculate equipment and refrigeration facilities (refrigeration and air conditioning).
3. Knowledge and ability to analyze, design, calculation and application of power cycles and alternative heat engines.
4. Knowledge about technology and applications of unconventional alternatives energy (geothermal energy, solar energy and fuel cells).
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Teaching methodology

1. - Classes with large groups: in these classes lectures are developed, but also some classes of problems. The professor will present the contents though lectures in order to achieve the main objectives of the course.

2. - Classes with small-to-medium groups: In these classes, problems will be worked out by both the teacher and the students. Discussions and group dynamics with the teacher and other students in the classroom will be possible; presentation of an activity individually or in small groups in the classroom will be also considered. Lab sessions with PC support and lab practices can also be made.

 ATENEA platform will be used as support for the two types of classes described. It will be used as a media for communicating with the students.
 a) Teacher to students:
 1. - Scheduling of activities and providing information
 2. - Learning Material
 3. - Evaluations of activities
 b) Student to teachers:
 1. - Questions and comments about the different modules
 2. - Handing in assessment exercises and lab reports
 c) Between Students
 1. - Using the FORUM as a place for information and discussion

Learning objectives of the subject

- Acquiring a broad overview fuel cells, battery types, thermodynamic and electrical fundamentals, the reasons why there are efficiency losses and fem Falls and the state of technology in the different types of fuel cells both low temperature and intermediate and high. Affect their current and future applications and development trends.

- To acquire knowledge on the availability of solar energy and the development and use of this energy in thermal systems. Knowing the equipment and systems used for both low temperature (hot water, heating, etc.) and high temperature for the production of electricity using concentrated solar energy. Acquire the knowledge to assess and design the equipment and solar thermal energy. Acquire knowledge about different standards testing equipment and solar thermal systems, and the various environmental laws and regulations.

- To acquire the ability to analyze the behavior of a geothermal system, evaluate the performance of a geothermal power plant and assess the environmental impact of a geothermal power plant.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 187h 30m</th>
<th>Hours large group: 45h</th>
<th>24.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group: 22h 30m</td>
<td>12.00%</td>
</tr>
<tr>
<td></td>
<td>Self study: 120h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
(ENG) Module 2 - Solar thermal energy

<table>
<thead>
<tr>
<th>Learning time: 62h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 15h</td>
</tr>
<tr>
<td>Laboratory classes: 7h 30m</td>
</tr>
<tr>
<td>Self study : 40h</td>
</tr>
</tbody>
</table>

**Description:**

2. Radiant properties of the most common materials used in thermal solar energy: Basic concepts of the radiant properties of materials and their evaluation.


4. Thermal energy storage in solar thermal energy facilities. Study of the most used technologies for thermal energy storage facilities of low, medium and high temperature. Study of thermal stratification and its influence on the performance of solar thermal systems.

5. Solar heating systems: solar installations of low, medium and high temperature solar thermal plants. Evaluation, sizing and simulation of solar thermal systems: i) systems for domestic hot water and heating; ii) solar cooling (absorption) as domestic and industrial application; iii) solar thermal plants.

**Related activities:**
Activity 1: Lectures and problem classes
Activity 2: Assessment exercises (2)
Activity 3: Lab sessions (2)
Activity 4: Final Exam

**Specific objectives:**
To know which is the availability of solar energy to optimize its use. Being able to evaluate the angular position of the Sun and of estimating solar radiation on an inclined surface.

Deepen on the most used types of solar collectors and their materials properties. To evaluate the spectral properties of the materials.

Knowing the different technologies used to harness solar energy depending on the operating temperature range. Being able to evaluate, from a thermal point of view, both the useful energy and performance of a solar collector regardless of the technology used. Know the standards for testing a solar collector.

Knowing the different technologies used for thermal energy storage. Know the basic properties of different heat storage media. Assessing the thermal stratification in a thermal storage tank. Know the standards for testing a heat storage for low temperature applications.

Knowing the different technologies used depending on the range of temperatures. Know the different environmental aspects and ordinances related to solar thermal systems both low and high temperature. Knowing the different methodologies and programs for the calculation of solar thermal systems. Being able to perform the calculation and dimensioning of different types of solar thermal installations such as facilities for domestic water heating, absorption cooling installations, solar thermal plants.
## (ENG) MODULE 1 - Geothermal energy

<table>
<thead>
<tr>
<th>Description:</th>
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### Learning time:
- **Theory classes:** 21h
- **Laboratory classes:** 10h 30m
- **Self study:** 56h
1. - Introduction: origin of geothermal energy.
1.1 The Earth's crust.
1.2 Plate tectonics and geothermal anomalies.
1.3 Origin of heat.
1.4 Balances of heat in the Earth's crust and mantle.

2. - The porous and fractured media.
2.1 Characteristics of porous media.
2.2 Porosity and hydraulic conductivity.
2.3 Basic equations. Flow at high Reynolds number.
2.4 Groundwater flow.
2.5 Groundwater flow in discontinuous media (fractured media).

3. - Heat transfer in porous media.
3.1 Basic equations.
3.2 Transport by conduction and convection. Analytical solutions.
3.3 Vertical flow. Bredehoeft and Papadopoulos analytical solution.
3.4 Dimensionless numbers.

4. - Geothermal systems.
4.1 Vapor and liquid-dominant systems.
4.2 Typological classification: convective and conductive systems.
4.3 Examples.

5. - Geothermometers.
5.1 Characteristics of geothermal fluids.
5.2 Solute geothermometers.
5.3 Gas geothermometers.
5.4 Isotopic geothermometers.
5.5 Practical calculations.

6. - Exploitation of geothermal fluids.
6.1 Drilling of geothermal wells.
6.2 Hydraulics of confined systems.
6.3 Hydraulics of unconfined systems.
6.4 Pumping tests. Power calculation.

7. - Geothermal Power Plants.
7.1 Dry steam plants.
7.2 Flash geothermal plants.
7.3 Binary geothermal plants.
7.4 Enhanced geothermal systems.

8. - HVAC applications.
8.1 Soil temperature.
8.2 Main systems: open and closed (loops).
8.3 Vertical Systems or geothermal probes.
8.4 Construction Procedures.

9. - Modeling of geothermal systems.
9.1 Basic equations.
### 9.2 Code "Hydroterm".

### 9.3 Examples.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Dry steam system: Larderello.</td>
</tr>
<tr>
<td>10.2</td>
<td>Mixed system: Cerro Prieto.</td>
</tr>
<tr>
<td>10.3</td>
<td>Geothermal systems of the Iberian Peninsula.</td>
</tr>
</tbody>
</table>

### 10. - Exploitation of geothermal systems.

- **10.1 Dry steam system:** Larderello.
- **10.2 Mixed system:** Cerro Prieto.
- **10.3 Geothermal systems of the Iberian Peninsula.**

### 11. - Environmental Impact of Geothermal Energy.

- **11.1 Effects on the water quality.**
- **11.2 Gaseous emissions.**
- **11.3 Remedial measures.**

#### Related activities:
- Activity 1: Lectures and problem classes
- Activity 2: Lab sessions (3)
- Activity 3: Final Exam

#### Specific objectives:
- Ability to analyze the behavior of a geothermal system.
- Ability to evaluate the behavior of a geothermal power plant.
- Ability to evaluate the environmental impact of a geothermal power plant.
(ENG) MODUL 3 - Fuel cells

Learning time: 37h 30m
Theory classes: 9h
Laboratory classes: 4h 30m
Self study: 24h

Description:


Related activities:
Activity 1: Lectures and problem classes
Activity 2: Assessment exercises (4)
Activity 3: Final Exam

Specific objectives:
To acquire an overview on fuel cells, battery types, thermodynamic and electrical fundamentals, the causes of efficiency loss and f.e.m reduction and the state of the art in the different types of fuel cells both low and medium to high temperature. Study their current and future applications and development trends.
## Planning of activities

### Theoretical and practical exercises classes

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Methodology in a large group.</td>
</tr>
<tr>
<td>Exposure of the content of the course following an expository and participative model.</td>
</tr>
<tr>
<td>Support materials:</td>
</tr>
<tr>
<td>Notes available on the Atenea platform.</td>
</tr>
<tr>
<td>Main literature for the course</td>
</tr>
<tr>
<td>Descriptions of the assignments due and their relation to the assessment:</td>
</tr>
<tr>
<td>During some sessions face-to-face exercises will be conducted, individually or in small groups.</td>
</tr>
<tr>
<td>Specific objectives:</td>
</tr>
<tr>
<td>Transfer the knowledge necessary for a correct interpretation of the contents in the large group sessions, resolving doubts in relation to the content of the course and development of generic skills.</td>
</tr>
<tr>
<td>Hours: 128h 30m</td>
</tr>
<tr>
<td>Laboratory classes: 10h 30m</td>
</tr>
<tr>
<td>Theory classes: 42h</td>
</tr>
<tr>
<td>Self study: 76h</td>
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</tbody>
</table>

### Lab sessions

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>During these activities, laboratory activities for test equipment and systems studied in the course, as well as computer support activities will be conducted.</td>
</tr>
<tr>
<td>Support materials:</td>
</tr>
<tr>
<td>Notes and material provided by the professor via atenea</td>
</tr>
<tr>
<td>Descriptions of the assignments due and their relation to the assessment:</td>
</tr>
<tr>
<td>Report on the results obtained</td>
</tr>
<tr>
<td>Specific objectives:</td>
</tr>
<tr>
<td>Acquire the skills necessary for a proper assessment of equipment and systems.</td>
</tr>
<tr>
<td>Hours: 36h</td>
</tr>
<tr>
<td>Laboratory classes: 12h</td>
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<tr>
<td>Self study: 24h</td>
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</tbody>
</table>

### Sessions of guided activities

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Pre- and post-preparation sessions about the guided activities.</td>
</tr>
<tr>
<td>Support materials:</td>
</tr>
<tr>
<td>Notes available on the Atenea platform.</td>
</tr>
<tr>
<td>General Bibliography of the course</td>
</tr>
<tr>
<td>Exercises available on the Athena platform</td>
</tr>
<tr>
<td>Descriptions of the assignments due and their relation to the assessment:</td>
</tr>
<tr>
<td>The students will work out the practical exercises handed ou by the professor in an autonomous manner.</td>
</tr>
<tr>
<td>Hours: 20h</td>
</tr>
<tr>
<td>Self study: 20h</td>
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**Specific objectives:**
Acquire the skills necessary for a correct interpretation of the problems of the subject, as well as a satisfactory resolution of generic skills development.

<table>
<thead>
<tr>
<th>Exams</th>
<th>Hours: 3h</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 3h</td>
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**Description:**
Individual and written tests on the modules content.

**Support materials:**
Test questions

**Descriptions of the assignments due and their relation to the assessment:**
Exam with the solutions to the posed questions

**Specific objectives:**
The student should prove that has the basic knowledge required for fulfilling the exam.

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**Qualification system**

- Exercises and / or laboratory tests in the field of solar thermal energy: 16.7%
- Exercises and / or laboratory test in the field of geothermal energy: 23.3%
- Exercises and / or laboratory test in the field of fuel cells: 10%
- Final exam for the course: 50%. In the final exam the student would has the option of recovering the qualifications from the assessment exercises and/or lab sessions.

For those students who meet the requirements and submit to the reevaluation examination, the grade of the reevaluation exam will replace the grades of all the on-site written evaluation acts (tests, midterm and final exams) and the grades obtained during the course for lab practices, works, projects and presentations will be kept.

If the final grade after reevaluation is lower than 5.0, it will replace the initial one only if it is higher. If the final grade after reevaluation is greater or equal to 5.0, the final grade of the subject will be pass 5.0.

**Regulations for carrying out activities**

Individual and written exam about the contents of the modules. The tests must demonstrate that the student has acquired and assimilated the concepts, principles and fundamentals related to the modules of the course.
Bibliography

Basic:


Larminie, J; Dicks, A. Fuel cell systems explained. 2nd ed. Chichester [etc.]: John Wiley & Sons, cop. 2003. ISBN 047084857X.


Complementary:


Others resources:

Audiovisual material
Transparències, problemes proposats que es faran servir a classe
Slides

Computer material
Apunts d’energia solar tèrmica per a l’assignatura d’Alternatives Energètiques
Notes on solar thermal energy for the course 'Alternatives Energètiques'

Apunts de plies de combustibles per a l’assignatura d’alternatives energètiques
Notes on fuel cells for the course 'Alternatives Energètiques'