Course guides
220283 - 220283 - Renewable Energy

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Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2013). (Optional subject).

Academic year: 2020 **ECTS Credits:** 7.5 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: 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).

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

- Acquire knowledge about the availability of solar energy, as well as the use and use of this energy in thermal installations. Know the equipment and the most used facilities for both low temperature (hot water, heating, etc.) and for high temperature for the production of electric energy with concentrated solar energy. Acquire the knowledge to evaluate and design equipment and solar thermal energy systems. Acquire knowledge about the different standards of testing equipment and solar thermal systems, as well as the different environmental regulations and regulations.
- Acquire a broad vision on fuel cells, battery types, thermodynamic and electrical foundations, the causes for which there are losses of efficiency and fall of the fabric, as well as the state of the technology in the different types of fuel cells, both low temperature and intermediate and high. Focus on your current and future development applications and trends.
- Acquire knowledge about absorption cooling systems and the ability to analyze the behavior of a cycle, evaluate the behavior of an absorption machine.

STUDY LOAD

Type	Hours	Percentage
Hours small group	22,5	12.00
Self study	120,0	64.00
Hours large group	45,0	24.00

Total learning time: 187.5 h

CONTENTS

(ENG) Module 2 - Solar thermal energy

Description:
1. Introduction . Availability of solar energy : solar radiation basics and availability. Estimation of solar radiation available depending on the geographic location.

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

3 . Solar thermal collectors : Solar thermal collectors for low, medium and high temperature (high temperature solar receivers) . Principles of operation. Study of the different heat transfer mechanisms . Defining the performance of a solar collector . Test of a low-temperature solar collector .

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 .

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.

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

Full-or-part-time: 86h
Theory classes: 20h
Laboratory classes: 10h
Self study : 56h

title english

Description:
- Introduction: brief historical review, physical principle, thermodynamic analysis of absorption cycles: definition of the performance indicators, analysis of cycles by absorption.

- Thermodynamic analysis of the absorption cycle: definition of COP, T-s and p-h diagrams, comparison with the Rankine cycle.

- Working fluids: systems with volatile absorbent (H2O-NH3) and non-volatile (LiBr-H2O). Technological implications: simple effect, double effect, multiple effect (LiBr-H2O), dual absorption cycle, GAX cycles (H2O-NH3). Other couples coolant-absorbent. Cooling of the absorption machines: cooling towers and cooling by air.

- Complete system analysis and absorption cycle: design and prediction. Use of zero-dimensional and global balance based models in permanent and transient conditions. Study of the influence of external conditions on the system.

- Overview of absorption cooling applications, together with advanced cycle configurations adapted.

Specific objectives:
- Acquire knowledge about absorption cooling systems and the ability to analyze the behavior of a cycle, evaluate the behavior of an absorption machine.

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

Full-or-part-time: 51h
Theory classes: 12h 30m
Laboratory classes: 6h 30m
Self study : 32h

(ENG) MODUL 3 - Fuel cells

Description:
1.- Fundamentals of fuel cells . General characteristics . Battery Type. Alkaline batteries, phosphoric acid cells with proton exchange membrane , molten carbonate cells and solid oxide cells . Regenerative batteries. Applications . Environmental impact. -

2. - Theoretical foundations of fuel cells . Electromotive force of a battery. E.M.F, work and heat . Effect of temperature and pressure on the E.M.F. Effect of concentration . Efficiency of a fuel cell . Dependence of efficiency with temperature. Practical efficiency.

3. - : Operational fuel cell. Irreversibilities . Activation losses . Losses due to the passage of fuel. Losses due to internal currents . Mass transport losses or change in concentration . Ohmic losses . Electrode mechanisms . Electrocatalysis . Determining air flow , oxygen , water and fuel . Heat produced .

4. - : Technological Development . Alkalinebattery with static and moving electrolyte . Batteries with proton exchange membrane : operating principle , electrodes , membranes , electrolyte. Water management in a PEMFC . Effect of pressure on the PEMFC . Practical applications .

5 . - : Fuel cells of medium and high temperature. Phosphoric acid batteries : fundamentals and applications. Application for cogeneration . Molten carbonates fuel cells: fundamentals. Components of a MCFC . Internal reform . Effect of the oxidizing gas composition , temperature and pressure . Applications of MCFC . Solid oxide batteries : fundamentals and components. Practical design . Characteristics: effect of pressure and temperature . Combined cycle: battery - gas turbines.

6. - Methods of obtaining hydrogen . Steam reforming . Method of non-catalytic and catalytic oxidation . Autothermal reforming . Catalytic decomposition . Methods of internal fuel reformation .

Specific objectives:
To acquire an over view 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.

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

Full-or-part-time: 50h 30m
Theory classes: 12h 30m
Laboratory classes: 6h
Self study : 32h

ACTIVITIES

Theoretical and practical exercises classes

Description:
Methodology in a large group.
Exposure of the content of the course following an expository and participative model.

Specific objectives:
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.

Material:
Notes available on the Atenea platform.
Main literature for the course

Delivery:
During some sessions face-to-face exercises will be conducted, individually or in small groups.

Full-or-part-time: 128h 30m
Theory classes: 42h
Laboratory classes: 10h 30m
Self study: 76h

Lab sessions

Description:
During these activities, laboratory activities for test equipment and systems studied in the course, as well as computer support activities will be conducted.

Specific objectives:
Acquire the skills necessary for a proper assessment of equipment and systems.

Material:
notes and material provided by the professor via atenea

Delivery:
Report on the results obtained

Full-or-part-time: 36h
Laboratory classes: 12h
Self study: 24h

Sessions of guided activities

Description:
Pre- and post-preparation sessionsabout the guided activities.

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.

Material:
Notes available on the Atenea platform.
General Bibliography of the course
Exercises available on the Athena platform

Delivery:
The students will work out the practical exercises handed ou by the professor in an autonomous manner.

Full-or-part-time: 20h
Self study: 20h

Exams

Description:
Individual and written tests on the modules content.

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

Material:
Test questions

Delivery:
Exam with the solutions to the posed questions

Full-or-part-time: 3h
Theory classes: 3h

GRADING 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.

EXAMINATION RULES.

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:
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- Tiwari, G.N. Solar energy: fundamentals, design, modelling and applications. Pangbourne, UK: Alpha Science International, cop. 2002. ISBN 9781842651063.
- Vogel, W.; Kalb, H. Large-scale solar thermal power: technologies, costs and development. Weinheim: Wiley-VCH, cop. 2010. ISBN 9783527405152.
- Duffie, J.A.; Beckman, W.A. Solar engineering of thermal processes. 3rd ed. New York [etc.]: John Wiley & Sons, cop. 2006. ISBN 9780471698678.
- Herold, K.E.; Radermarcher, R.; Klein, S.A. Absorption chillers and heat pumps. Boca Raton[etc.]: CRC, 1996. ISBN 0849394279.
- Kordesch, K.; Simader, G. Fuel cells and their applications. Weinheim [etc.]: VCH, cop. 1996. ISBN 3527285792.
- Larminie, J; Dicks, A. Fuel cell systems explained. 2nd ed. Chichester [etc.]: John Wiley & Sons, cop. 2003. ISBN 047084857X.

Complementary:
- Beckman, W.A.; Klein, S.A.; Duffie, J.A. Solar heating design: by the f-chart method. New York [etc.]: John Wiley & Sons, cop. 1977. ISBN 0471034061.
- Stobart, Richard (ed.). Fuel cell technology for vehicles. Warrendale, PA: Society of Automotive Engineers, Inc, cop. 2001. ISBN 0768007844.
- Hoogers, Gregor (ed.). Fuel cell technology: handbook. Boca Raton [etc.]: CRC, cop. 2003. ISBN 0849308771.
- Srinivasan, Supramaniam. Fuel cells: from fundamentals to applications. New York [etc.]: Springer, cop. 2006. ISBN 9780387251165.
- Gordon, Jeffrey (ed.). Solar energy: the state of the art: ISES position papers. London: James & James, cop. 2001. ISBN 1902916239.
- Alefeld, G.; Radermarcher, R. Heat conversion systems. Boca Raton [etc.]: CRC Press, cop. 1994. ISBN 0849389283.
- Winter, C.J.; Sizmann, R.L.; Vant-Hull, L.L. (eds.). Solar power plants: fundamentals, technology, systems, economics. Berlin [etc.]: Springer-Verlag, cop. 1991. ISBN 3540188975.
- Bogart, Marcel. Ammonia absorption refrigeration in industrial processes. Houston [etc.]: Gulf Publishing Company, 1981. ISBN 0872010279.

RESOURCES

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

Computer material:
- Apunts de piles de combustibles per a l'assignatura d'alternatives energètiques. Notes on fuel cells for the course 'Alternatives Energètiques'
- Apunts d'energia solar tèrmica per a l'assignatura d'Alternatives Energètiques. Notes on solar thermal energy for the course 'Alternatives Energètiques'