Course guide
820744 - ESTM - Solar Thermal Energy

Last modified: 23/05/2024

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2014). (Optional subject).
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2022). (Optional subject).

Academic year: 2024 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Ivette Rodríguez

Others: Ivette Rodríguez

PRIOR SKILLS

Fundamental aspects of thermodynamics, fluid mechanics and heat transfer required to understand the operation of solar thermal systems.

REQUIREMENTS

Those equivalent to have passed the Master leveling course

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

TEACHING METHODOLOGY

During the development of the course the following teaching methods will be used:

-Lecture or conferences (EXP): Lectures taught by the professors of the course as well as invited lectures.
-Interactive classes (parts): resolution of exercises, collective discussions with both the teacher and the students. Presentation by the students of exercises carried out individually or in small groups.
-Oriented theoretical-practical works (TD): completion of a classroom activity, theoretical or practical, carried out individually or in small groups with the teacher's guidance.
- Project, activity or work of reduced scope (PR): Self-learning based on accomplishing an activity of reduced scope, individually or in small groups, just applying the knowledge acquired.
- Project or work of broader scope (PA): Self-learning based on accomplishing an activity of broader scope, individually or in small groups, just applying the knowledge acquired.
- Assessment exam (EV).

LEARNING OBJECTIVES OF THE SUBJECT

- know the different heat transfer phenomena (radiation, convection, conduction) that occur in equipment and solar thermal systems.
- Know the most common materials and their properties used in solar thermal applications such as selective treatments, phase change materials, transparent insulating surfaces, etc..
- Have a knowledge of the different methodologies that allow the design and calculation of solar thermal systems and equipment. Use of different calculation software both commercial and in-house codes developed at CentreTecnològic Heat Transfer, Technical University of Catalonia.
- Performing different practices for testing of solar thermal collectors and solar thermal systems.
- Know the different applications of solar energy such as absorption cooling systems, solar thermal energy as a primary source of energy systems for the production of electricity with solar thermal concentration (plants solar thermo-electric).

STUDY LOAD

Type	Hours	Percentage
Hours medium group	15,0	11.54
Self study	85,0	65.38
Hours large group	30,0	23.08

Total learning time: 130 h

CONTENTS

Introduction .

Description:
Availability of solar energy. Basic concepts of solar radiation and its availability. Estimation of available solar radiation depending on geographical location. Introduction to solar thermal installations and their equipment.

Specific objectives:
-Acquire the appropriate knoledge about the solar energy resources, its availability and how to use it in an optimize manner.
-Being capable of evaluating the angular position of the Sun
-Being capable to estimate solar radiation on a tilted surface
-To know different installations used to harness thermal energy and their classification based on the range of operating temperatures.

Related activities:
-Lectures or conferences
-Interactive classes
-Project, activity or work of reduced scope

Related competencies :
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.
CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.

Full-or-part-time: 17h
Theory classes: 6h
Laboratory classes: 1h
Self study : 10h

Most common materials used in thermal solar energy and their properties

Description:
Basic concepts of the radiant properties of materials and their evaluation.

Specific objectives:
- To go over previous acquire knowledge about radiant properties of materials for both opaque and transparent surfaces.
- To deepen in the knowlege about most common used materials in solar thermal collectors and their properties.
- To evaluate the spectral properties of the materials.
- To evaluate the gains of a solar absorber

Related activities:
lectures and conferences
Interactive classes

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

Full-or-part-time: 11h
Theory classes: 3h
Laboratory classes: 2h
Self study : 6h

Solar thermal collectors

Description:
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.

Specific objectives:
-Acquire the knowledge about the different technologies used to harness solar energy dependending on the temperature of operation.
-Being able to assess from a thermal point of view the useful energy performance of a receiver regardless of the technology used.
-Know the standard for testing a solar collector.
-Perform a solar collector test.

Related activities:
-Lectures or conferences
-Interactive classes
-Oriented theoretical-practical works
-Project, activity or work of reduced scope

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.

Full-or-part-time: 30h
Theory classes: 8h
Laboratory classes: 2h
Self study : 20h

Solar thermal storage

Description:
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 .

Specific objectives:
- Be aware of the different technologies used for the thermal energy storage
- Acquire the knowledge about the main properties of the different media used in thermal storage according to the type of technology
-Importance and evaluation of thermal stratification in a thermal storage system.
-Know the standards for testing a thermal energy storage system for low temperature applications

Related activities:
-Lectures or conferences
-Interactive classes
-Project, activity or work of reduced scope

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.

Full-or-part-time: 21h
Theory classes: 4h
Laboratory classes: 2h
Self study : 15h

Solar thermal systems

Description:
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 thermal plants .

Specific objectives:
- Acquire the knowledge about the different technologies used depending on the range of working temperatures.
- Be aware of the different aspects of environmental regulations and related installations of solar thermal as low and high temperature.
- Acquire the knowledge about the different methodologies and programs for the calculation of solar thermal installations
-Being able to perform the calculation and dimensioning of the different types of solar thermal installations such as facilities for domestic hot water and heating, thermo-solar plants

Related activities:
-Lectures or conferences
-Interactive classes
-Oriented theoretical-practical work
-Project, activity or work of reduced scope
-Project, activity or work of broader scope

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.
CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.

Full-or-part-time: 46h
Theory classes: 9h
Laboratory classes: 3h
Self study : 34h

ACTIVITIES

lectures and theoretical classes

Description:
The content of the course is taught 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 exposed by the professor with the participation of the students.

Related competencies :
CEMT-1. Understand, describe and analyse, in a clear and comprehensive manner, the entire energy conversion chain, from its status as an energy source to its use as an energy service. They will also be able to identify, describe and analyse the situation and characteristics of the various energy resources and end uses of energy, in their economic, social and environmental dimensions, and to make value judgments.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

Full-or-part-time: 40h
Self study: 10h
Theory classes: 30h

participative classes

Description:
In these actitivities, problems and exercises will be worked out following a participative scheme.

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:
The students will work out exercises, individually or in small groups, followed by the face-to-face presentation of the results.

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.

Full-or-part-time: 25h
Self study: 15h
Laboratory classes: 10h

name english

Description:
The student will carry out exercises oriented to deepen into the subjects taught in classes. These works can be carried out individually or in small groups.

Specific objectives:
-Being able to apply the knowledge acquired both theoretical and practical to carry out the work.
- The student must be able to demonstrate and apply their knowledge on heat transfer to resolve the behaviour of solar thermal equipment.
- From the results, theoretical and practical solutions to improve the performance of solar thermal equipment should be proposed.

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

Delivery:
Report on the results obtained

Related competencies :
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

Full-or-part-time: 30h
Self study: 30h

name english

Description:
Broad scope work in which students will implement and integrate the acquired knowledge to the study the performance of a solar thermal system. This work can be done on any of the technologies studied in the course.

Specific objectives:
-The student must be able to demonstrate and apply his/her knowledge through a system evaluation
-Understand the dependence of the different parameters on the solar fraction, system performance and in general, heat losses in the different equipment.
-Being able to provide solutions to improve the solar thermal installation.

Material:
Recommended bibliography. Notes and transparencies. Journal articles related to the subject.

Delivery:
Report on the results and their analysis. Solutions to improve both the solar fraction and the performance of the solar installation should be provided.

Related competencies :
CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.
CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.
CEMT-4. Efficiently collect data on renewable energy resources and their statistical treatment and apply knowledge and endpoint criteria in the design and evaluation of technology solutions for using renewable energy resources, for both isolated systems and those connected to networks. They will also be able to recognise and evaluate the newest technological applications in the use of renewable energy resources.

Full-or-part-time: 30h
Self study: 30h

GRADING SYSTEM

-Final exam (PE): 50%
-Assessment exercises (individually or in small groups) (TR): 40%
-Attendance and participation in classes and laboratories (AP): 5%
-Quality and performance of the work in groups (TG): 5%

During fall semester of the 2020-2021 academic year, and as a result of the health crisis due to Covid19, the qualification method will be:

There will be three assessments exercises to be developed along the course, the final (the third one) will involve aspects developed during the course. In addition to this a final test is also considered

The final grade will be obtained from the continuous evaluation and the final exam following the formula:
final mark = 0.4(assessment_1 + assessment_2)/2 + 0.35 x assessment_3 + 0.25 x final_exam

EXAMINATION RULES.

- Final exam (PE): There will be a final exam for the course. Students must complete both theoretical questions and problems related to theoretical and practical content of the course. Reviews and / or complaints regarding exams will be conducted in accordance with the dates and times established in the academic calendar.

- Assessment exercises (TR): Students must follow the instructions explained in class and contained in the work file that will be proposed to the students. As a result of these activities, the student must submit a report (preferably in pdf format) to the teacher, within the deadline fixed for each activity. The assessment will involve both its realization as a possible defense.

-Attendance and participation in classes and laboratories (AP): Laboratory practices are assessed both during the development of the lab and by accomplishing a practical exercises proposed; The report resulting from the lab will be handed in to the professor following the instructions given in class. The assessment will involve both practical realization, as a possible defense.

- Quality and performance of group work (TG): Practices and class exercises will be assessed individually or in small groups by means of their oral defense if necessary.

BIBLIOGRAPHY

Basic:
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- Duffie, J. A.; Beckman, W. A. Solar engineering of thermal processes [on line]. 5th ed. Hoboken: Wiley, 2020 [Consultation: 02/12/2024]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/9781119540328. ISBN 9781119540328.
- Tiwari, G. N. Solar energy : fundamentals, design, modelling and applications. Pangbourne, UK: Alpha Science International, cop. 2002. ISBN 9781842651063.
- Vogel, Werner; Kalb, Henry. Large-scale solar thermal power : technologies, costs and development [on line]. Weinheim: Wiley-VCH, cop. 2010 [Consultation: 27/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9783527629992. ISBN 9783527405152.

Complementary:
- Winter, C.-J; Sizmann, Rudolf L; Vant-Hull, Lorin L. Solar power plants : fundamentals, technology, systems, economics. Berlin [etc.]: Springer-Verlag, cop. 1991. ISBN 3540188975.
- Beckman, William A; Klein, Sanford A; Duffie, John A. Solar heating design : by the f-chart method. New York [etc.]: John Wiley & Sons, cop. 1977. ISBN 0471034061.
- Gordon, Jeffrey. Solar energy : the state of the art : ISES position papers [on line]. James & James: London, cop. 2001 [Consultation: 15/11/2024]. Available on: https://www-taylorfrancis-com.recursos.biblioteca.upc.edu/books/edit/10.4324/9781315074412/solar-energy-jeffrey-gordon. ISBN 1902916239.

RESOURCES

Audiovisual material:
- Transparències. Resource

Computer material:
- Apunts i articles. Resource