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820761 - ITCMM - Advanced Course on Heat and Mass Transfer

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines
Academic year: 2019
Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 5 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: JESUS CASTRO GONZALEZ

Others: Carlos David Pérez Segarra, Assensi Oliva

Opening hours

Timetable: The specific timetable is personally agreed on with the student according to his/her availability

Prior skills

Prior skills: the general aspects of thermodynamics, fluid mechanics and heat and mass transfer.

Requirements

Requirements: Knowledge equivalent to completion of the levelling course of the Master's.

Degree competences to which the subject contributes

Specific:

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.

Transversal:

CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

Teaching methodology

Teaching methodology:

The course teaching methodologies are as follows:

- Lectures and conferences: presentation of knowledge by lecturers or guest speakers.
- Participatory sessions: collective resolution of exercises, debates and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work (TD): classroom activity carried out individually or in small groups, with the advice and supervision of the teacher.
- Homework assignment of reduced extension: carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension: design, planning and implementation of a project or homework of broad extension by a group of students, and writing a report that should include the approach, results and conclusions.
- Evaluation activities (EV).

Training activities:

The course training activities are as follows:

- Face to face activities
o Lectures and conferences: learning based on understanding and synthesizing the knowledge presented by the teacher or by invited speakers.
o Participatory sessions: learning based on participating in the collective resolution of exercises, as well as in discussions and group dynamics, with the lecturer and other students in the classroom.
o Presentations (PS): learning based on presenting in the classroom an activity individually or in small groups.
o Theoretical/practical supervised work (TD): learning based on performing an activity in the classroom, or a theoretical or practical exercise, individually or in small groups, with the advice of the teacher.

- Study activities
o Homework assignment of reduced extension (PR): learning based on applying knowledge and presenting results.
o Homework assignment of broad extension (PA): learning based on applying and extending knowledge.
o Self-study (EA): learning based on studying or expanding the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing knowledge.

Learning objectives of the subject

Objectives:

Formation, at a medium level, in heat transfer by conduction, convection and radiation and fluid dynamics: phenomenological aspects, mathematical formulation (basic conservation laws and constitutive laws) and analytical and numerical resolution techniques. Methodologies of resolution of problems of technological interest which different forms of combined heat transfer are presented.

Learning results:

At the end of the course, the student:
- Intensification in the physical description of the phenomena of heat and mass transfer and its mathematical formulation.
- Application of different computational techniques for the numerical solution of these phenomenologies.
- Development of in-house numerical codes to the study of fluid dynamic and thermal behaviour of different cases of technological interest and motivating for students. Emphasis is placed on aspects of code verification, verification of numerical solutions obtained and validation of the mathematical formulation used.

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Study load

Total learning time: 125h 03m	Hours large group:	0h	0.00%
	Hours medium group:	0h	0.00%
	Hours small group:	30h	23.99%
	Guided activities:	1h 42m	1.36%
	Self study:	93h 21m	74.65%

Content

Mathematical formulation of heat transfer and fluid dynamics	Learning time: 21h 30m Theory classes: 5h Guided activities: 1h 30m Self study : 15h

Description:
Basic mathematical formulation as integral phenomena of fluid dynamics and heat transfer: isolated systems, closed systems, interaction with the outside view of Euler and Lagrange (particle and finite volume); open systems. Vector and tensor notation. Mathematical formulation in differential form: basic equations (conservation of mass, momentum, energy, entropy) and derivative equations (kinetic energy, vorticity, heat, exergy,...). Constitutive laws.

Related activities:
- Theory classes
- Practical classes
- Guided activities
- Reduced scope work
- Broad scope work

Specific objectives:
Introduction to basic mathematical formulations of fluid dynamics and heat and mass transfer.

Introduction to turbulence	Learning time: 25h Theory classes: 6h Guided activities: 2h Self study : 17h

Description:
Introduction to the mathematical formulation of turbulent flows. Physical fundamentals of turbulence and statistical characterisation. Direct numerical turbulence (DNS, Direct Numerical Simulation): Possibilities and limitations. Navier-Stokes equations temporarily averaged and turbulence models RANS (Reynolds-Averaged Navier Stokes): high and low Reynolds two-equation models, wall functions, differentially-stress models, etc. Basic mathematical formulation of LES (Large Eddy Simulation) model types, average volume. Brief introduction to numerical methods for solving the Navier-Stokes equations.

Related activities:
- Theory classes
- Practical classes
- Guided activities
- Reduced scope work
- Broad scope work

Specific objectives:
Introduction to basic mathematical formulations of fluid dynamics and heat and mass transfer.

Zonal resolution of convection. Boundary layer and potential zone.	Learning time: 28h 30m Theory classes: 7h Guided activities: 2h 30m Self study : 19h

Description:
Zonal resolution of flows by division in non-viscous region and boundary layers (hydrodynamic and thermal). Formulation of equations for a non-viscous zone (Euler equations). Formulation of the equations for laminar and turbulent boundary layers (orders of magnitude analysis). Review of analytical solutions of the equations of the laminar boundary layers (hydrodynamic and thermal) in isothermal plates and integral methods. Introduction to numerical methods for resolving laminar and turbulent boundary layers. Coupling of the non-viscous zone and boundary layers (thickness concept of displacement and general zonal methods).

Related activities:
- Theory classes
- Practical classes
- Guided activities
- Reduced scope work
- Broad scope work

Specific objectives:
- Approach of a zonal resolution methodology of flows based on the division of non-viscous zones and boundary layers.
- Presentation of solutions for semi-empirical laminar boundary layer.
- Turbulent boundary layer structure and characterisation.

Heat transfer by radiation	Learning time: 25h Theory classes: 6h Guided activities: 2h Self study : 17h

Description:
Numerical radiation phenomena. Specific intensity of radiation. General formulation of the fundamental equation of radiation (RTE or Radiative Transfer Equation). Review of methods of analysis of radiation in non-participating media. Extension of the formulation to participating media. Introduction to numerical resolution techniques of intensity of spectral and directional radiation according to the DOM (Discrete Ordinate Methods) and FVM (Finite Volume Method) methods.

Related activities:
- Theory classes
- Practical classes
- Guided activities
- Reduced scope work
- Broad scope work

Specific objectives:
- Basic formulation of radiation.
- Review of methodologies of calculation in the case of non-participating media.
- Extension in the case of participating media with regard to character and directional spectral radiation. Numerical methods of resolution (DOM and FVM).

Vapour-liquid phase change	Learning time: 25h Theory classes: 6h Guided activities: 2h Self study : 17h

Description:

Analysis of the phenomenology of vapour-liquid phase change (condensation and evaporation). Mathematical formulation of the condensation film in isothermal vertical plates. Methods of analytical resolution and extension to complex situations using computational methods. Condensation on the outside of horizontal tubes. Phenomena of evaporation on open surfaces. Mathematical formulation of phenomenologies of fluid dynamics and heat and mass transfer. Fick's law and treatment of boundary conditions. Examples of resolution. Analysis of two-phase flows (condensation or evaporation) on the interior of ducts. Different levels of simulation.

Related activities:

- Theory classes
- Practical classes
- Guided activities
- Reduced scope work
- Broad scope work

Specific objectives:

- Detailed phenomenological description and mathematical formulation of the phenomena of evaporation and condensation on the exterior of surfaces. Specific techniques of numerical resolution.
- Detailed phenomenological description and mathematical formulation of evaporation and condensation phenomena on the interior of ducts. Detailed analysis of one-dimensional types (permanent or temporary).

Planning of activities

Theory classes	Hours: 40h Self study: 20h Theory classes: 20h

Description:

Methodology in large group. The content of the course will follow a model of exhibition class and participation. The material is organised into different groups according to the content areas of knowledge of the subject.

Support materials:

Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:

This activity is evaluated in conjunction with the second activity (problems) through coursework and testing knowledge.

Specific objectives:

At the end of this activity, students should be able to master the knowledge, consolidate them and apply them correctly to various technical problems. Moreover, being a techno-scientific subject, the lectures should serve as a basis for the development of other more technical subjects related to the field of heat, such as refrigeration, or Solar Thermal Engines.

Practical classes	Hours: 22h Guided activities: 2h Self study: 10h Theory classes: 10h

Description:

Methodology in large group and medium group, as long as the availability of the professor permits it. On each topic there will be some problems in the classroom so that students acquire the necessary guidelines to carry out this resolution: simplifying assumptions, approach, numerical resolution, discussion of results.

Support materials:

Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:

This activity is evaluated in conjunction with the first activity (theory) through coursework and exams.

Specific objectives:

At the end of this activity, students should be able to apply theoretical knowledge to solve different types of problems. Given the methodology, students should be able to:
1.- Understand the statement and analyse the problem.
2.- Propose and develop a scheme of the same resolution.
3.- Solve the problem using proposed equations with a suitable algorithm resolution.
4.- Critically interpret the results.

Guided activities	Hours: 12h Guided activities: 2h Self study: 10h

Description:

Students must perform guided activities. The activities consist in solving small problems, of which the data may be the result of a laboratory experiment or proposed data by the professor. The structure to be followed:
- Preparation of the activity by a manual of practice.
- Groups of 2 or 3 people with a maximum duration of two hours.
- Discussion of the results obtained and the problems that have arisen during the course of practice.
- Completion of a report on the practice carried out with results, questions and conclusions. This report will be evaluated together with the completion of the practice.

Support materials:

Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:

Reports should follow guidelines given in class.

Specific objectives:

Consolidate the knowledge acquired in theory classes and practices.

Reduced scope work	Hours: 12h Guided activities: 2h Self study: 10h

Description:

Resolution of two problems based on situations posed by the professor.

Support materials:

Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:

The report should follow guidelines given in class.

Specific objectives:

Consolidate the knowledge acquired in theory classes and practices.

Broad scope work	Hours: 17h Guided activities: 2h Self study: 15h

Description:

Resolution of a problem based on situations posed by the professor or student.

Support materials:

Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:

The report should follow guidelines given in class.

Specific objectives:

Expand and consolidate the knowledge acquired in theory classes and practices.

Written test	Hours: 22h Guided activities: 2h Self study: 20h

Description:
Development of a written test of the course contents 1 and 2. It includes theoretical aspects and development problems.

Support materials:
Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:
The exam will be held freely and the statement delivered along with the statement duly filled in with the data required.

Specific objectives:
Demonstrate the level of knowledge achieved in theoretical activities and problems.

Qualification system

Midterm exam: 20%
Final exam: 35%
Works developed individually or in groups throughout the course (TR): 45%

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Regulations for carrying out activities

Here are the rules of the system for evaluating the educational activities of the course.

Written test (PE).

There will be a final exam for the course. Students must complete both theoretical questions and problems related to the theoretical and practical content of the course. Reviews and/or claims regarding the examinations will be conducted according to the dates and times established in the academic calendar.

Work done individually or in groups along the course (TR).

Students must follow the instructions explained in class and contained in the file for the work that will be proposed to the student in relation to different teaching content of the course. As a result of these activities, students must submit a report (preferably in PDF format) to the professor, with the deadline to be fixed for each activity. The evaluation work will involve both its realisation and a possible defense.

Attendance and participation in classes and laboratories (AP).

The labs will be assessed both in their implementation and in the implementation of practical exercises that will be proposed; they can begin during the class schedule planned for this type of activity to be completed (if applicable) as an autonomous activity, following the instructions given in class. The results of practical exercises delivered to the teacher must follow the instructions given in class.

The evaluation of the practice will involve both its realisation and a possible defense.

Quality and performance of group work (TG).

The reports of practices and/or group work will be assessed individually on the oral defense if necessary or of any single group on the report.

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Complementary:

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Anderson, John David. Computational fluid dynamics. 3rd ed. Berlin: Springer, 2009. ISBN 9783540850557.

Others resources:

Audiovisual material

Transparencies from class

Resource

Notes

Resource