Universitat de Lleida

DEGREE CURRICULUM

ANALYSIS OF INDUSTRIAL THERMAL EQUIPMENT

Coordination: DE GRACIA CUESTA, ÁLVARO

Academic year 2021-22

ANALYSIS OF INDUSTRIAL THERMAL EQUIPMENT 2021-22

Subject's general information

<table>
<tr><td>Subject name</td><td>ANALYSIS OF INDUSTRIAL THERMAL EQUIPMENT</td></tr>
<tr><td>Code</td><td>14540</td></tr>
<tr><td>Semester</td><td>2nd Q(SEMESTER) CONTINUED EVALUATION</td></tr>
<tr><td>Typology</td><td><table><tr><th>Degree</th><th>Course</th><th>Typology</th><th>Modality</th></tr><tr><td>Master's Degree in Industrial Engineering</td><td>2</td><td>OPTIONAL</td><td>Attendance-based</td></tr></table></td></tr>
<tr><td>Course number of credits (ECTS)</td><td>6</td></tr>
<tr><td>Type of activity, credits, and groups</td><td><table><tr><th>Activity type</th><td>PRAULA</td><td>TEORIA</td></tr><tr><th>Number of credits</th><td>3</td><td>3</td></tr><tr><th>Number of groups</th><td>1</td><td>1</td></tr></table></td></tr>
<tr><td>Coordination</td><td>DE GRACIA CUESTA, ÁLVARO</td></tr>
<tr><td>Department</td><td>INFORMÀTICA I ENGINYERIA INDUSTRIAL</td></tr>
<tr><td>Teaching load distribution between lectures and independent student work</td><td>60 h lectures (40%)
90 h independent student work (60%)</td></tr>
<tr><td>Important information on data processing</td><td>Consult this link for more information.</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Distribution of credits</td><td>Dr. Alvaro de Gracia 3 ECTS
Dr. Albert Oriol Castell Casol: 3 ECTS</td></tr>
</table>

Teaching staff	E-mail addresses	Credits taught by teacher	Office and hour of attention
CASTELL CASOL, ALBERT ORIOL	albert.castell@udl.cat	3	
DE GRACIA CUESTA, ÁLVARO	alvaro.degracia@udl.cat	3	
MEDRANO MARTORELL, MARCO	marc.medrano@udl.cat	0	

Subject's extra information

This course reviews and expands knowledge about heat transfer and thermodynamics, which are necessary for the proper design of many technologies commonly used today, such as domestic appliances, electronics, insulation of homes and facilities, car radiators, solar collectors, equipment for power plants or aerospace thermal designs. The course builds upon the basic principles of thermodynamics and the experimental laws for the different modes of heat transfer (Fourier Law for conduction, Newton law of cooling, for convection, and Stefan-Boltzmann law for radiation) so that the student is able to design and analyze different types of industrial thermal equipment, using both analytical and numerical resolution methods. Likewise, it introduces students to advanced numerical simulation tools, such as COMSOL Multiphysics, and infrared thermography. It is recommended to have a sufficient basis in heat transfer, thermodynamics and differential equations.

It is an optional subject that is delivered in the 2nd semester of the 2nd year of the Masters in Industrial Engineering. According to the structure of the degree, this optional subject is part of the Optional formation module, and the Energetic Systems module, along with the subject "Electrical machinery in industry." These two subjects share a common practice and aim for a common analysis of thermal and electrical aspects in problems and projects.

It is **COMPULSORY** that the students bring the following elements of individual protection (EPI) to the practices at the laboratory.

- Blue or white laboratory gown from UdL (unisex)
- Protection glasses
- Mechanical protection gloves

They can be purchased through the shop Údels of the UdL:

C/ Jaume II, 67 baixos
Centre the Cultures i Cooperació Transfronterera

http://www.publicacions.udl.cat/

The use of other elements of protection (for example caps, masks, gloves of chemical or electrical risk, etc.) will depend on the type of practice to be done. In that case, the teacher will inform of the necessity of specific EPI.

Not bringing the EPI's described or not fulfilling the norms of general security that are detailed below imply that the student can not access to the laboratories or have to go out of them. The no realisation of the practices for this reason imply the **consequences in the evaluation** of the subject that are described in this course guide.

GENERAL NORMS OF SECURITY IN LABORATORY PRACTICES

- Keep the place of realisation of the practices clean and tidy. The table of work has to be free from backpacks, folders, coats...
- No short trousers or short skirts are allowed in the laboratory.
- Closed and covered footwear is compulsory in the laboratory.
- Long hair needs to be tied.
- Keep the laboratoy gown laced in order to be protected from spills of chemicals.
- Bangles, pendants or wide sleeves are not allowed as they can be trapped.
- Avoid the use of contact lenses, since the effect of the chemical products is much bigger if they enter between the contact lense and the cornea. Protection over-glasses can be purchased.
- No food or drink is allowed in the laboratory.
- It is forbidden to smoke in the laboratories.
- Wash your hands whenever you have contact with a chemical product and before going out of the laboratory.
- Follow the instructions of the teacher and of the laboratory technicians and ask for any doubt on security.

For further information, you can check the following document of the *Servei de Prevenció de Riscos Laborals de la UdL*: http://www.sprl.udl.cat/alumnes/index.html

Learning objectives

GENERAL OBJECTIVE OF THE SUBJECT

To provide students with the knowledge and techniques, tools, skills and abilities required to effectively develop professional activities related to the analysis and design of industrial thermal equipment.

The achievement of this overall objective is based on:

- To learn to describe and solve the differential equations that define the heat transfer by conduction in solids
- To learn the Navier-Stokes equations and their applications in the use of dimensionless groups.
- To learn the theory of boundary layer and potential area
- To learn the mechanism of heat transfer by radiation from various surfaces
- To learn the numerical methods to solve problems with not integrable differential equations
- To know the CFD methodology for computation of heat transfer problems in solids and fluids
- To write with appropriate technical language, and with spelling and grammar correction.
- To learn how to publicly defend, with clear ideas and concepts and with appropriate technical language, an industrial thermal equipment project.

Competences

General competences

- **CG3** Capacity to convey information, ideas, problems and solutions both to a specialised and no specialised public.

- **CG4** Capacity to conceive, design and implement projects and/or provide new solutions, using the tools that the engineering offers.
- **CG7** To project, calculate and design products, processes, installations and plants.
- **CG9** To do research, development and innovation in products, processes and methods.

Specific competences

- **CE5** Knowledge and capacity for the design and analysis of heat engines, hydraulic machines and installations of heat and industrial refrigeration.

Cross-disciplinary competences

- **CT1** Appropriate skills in oral and written language.
- **CT2** Command of a foreign language.

Subject contents

Lectures programme

1. Basic thermal engineering

1.1 Physical Properties

1.2 Conduction

1.3 Convection

1.4 Radiation

2. Conduction

2.1 Introduction to Conduction

2.2 Differential equations at steady state

2.3 Analytical Solutions at steady state

2.4 Transient state

3. Numerical Methods

3.1 Introduction to Numerical Methods

3.2 Finite difference formulation

3.3 Energy balance method

3.3.1 1- D Steady state heat conduction

3.3.2 2-D Steady state heat conduction

3.3.3 Transient 1-D heat conduction

3.4 Optimization tools using numerical models

4. Convection

4.1 Introduction to convection

4.2 Navier-Stokes equations

4.3 Boundary layer and Potential Zone

4.4 Model Theory and Dimensional Analysis

4.5 Computational Fluid Dynamics (CFD)

5. Radiation

5.1 Introduction to radiation

5.2 Parameters defining the radiation

5.3 Method of radiosities

6. Combined problems

Lab practices

Presentation and application of infrared camera (to be done at the Mechatronics Lab)

Presentation and application of Comsol Multiphysics (to be done at L3 computers room)

Methodology

The methodological axes of the course will be divided into:

- **Flipped Learning:** The students learn new content using TIC out of the classroom and the lecturer identifies incorrect concepts or doubts.
- **Just-in-time sessions at class:** The lecturer provides feedback to the activities of flipped learning and the students do practical activities or individualized activities focussed on the incorrect concepts identified.
- **Master class:** In master classes the contents are presented orally by the lecturer with no active participation of the students. These classes will be done virtually during 2020/2021 course.
- **Problems resolution**: The lecturer solves some examples and proposed other exercises so the students can take active part of their learning process working and solving the problems, either individually or in group.
- **Team work**: The lecturer does a follow-up of the assignment of each group of students, and the students take active part of their learning process applying the theoretical knowledge to a complex case of study.
- **Laboratory:** The lecturer proposes a practical activity to the students, who can taker active part of their learning process applying the theoretical knowledge to a real case first hand.

Development plan

The development plan will follow the order of the contents. This plan may be subject to modifications throughout the course, depending on the number of students, the work groups, and the evolution of the group.

The chapters given by each teacher are detailed below.

- Chapter 1. Albert Castell
- Chapter 2. Albert Castell
- Chapter 3. Alvaro de Gracia

- Chapter 4. Albert Castell.
- Chapter 5. Alvaro de Gracia
- Chapter 6. Alvaro de Gracia

Chapters 1 2 and 3 will be developed between the week 1 and 8. T

Chapters 4, 5 and 6 will be developed between the weeks 10 and 15.

Evaluation

Evaluation activities	%	Dates	C/V (1)	I/G (2)	Observations
Exam	25	Week 9	C	I	Minimum mark of 3 to count for the average
Combined heat transfer project	20	Week 17	C	G	
Numerical methods project	30	Week 17	C	I	
CFD assignment	25	Week 17	C	G	
Recovery exam	25	Week 18/19	C	I	Minimum mark of 3 to count for the average

(1) Compulsory/Voluntary

(2) Individual/Group

Bibliography

Basic Bibliography

- Y. Çengel, 'Heat Transfer: A Practical Approach', 2nd Edition, McGrawHill ,2003.
- T. Bergman, A. Lavine, F. Incropera, D. Dewitt, ' Fundamentals of Heat and Mass Transfer', 7th Edition, John Wiley & Sons, 2011.

Complementary Bibliography

- G.Nellis, S. Klein. 'Heat Transfer', Cambridge University Press, 2009.
- M.Fogiel. ' Heat transfer problem solver', REA, 1999.
- F. Krerten, M. Bohn. ' Principios de transferencia de calor' Thomson, 2001.

Other resources

- Thermal Imaging Guidebook for Industrial Applications, 2011, FLIR Systems AB (http://www.flirmedia.com/MMC/THG/Brochures/T820264/T820264_EN.pdf)