



Universitat de Lleida

DEGREE CURRICULUM  
**ANALYSIS OF INDUSTRIAL  
THERMAL EQUIPMENT**

Coordination: DE GRACIA CUESTA, ÁLVARO

Academic year 2019-20

## Subject's general information

<b>Subject name</b>	ANALYSIS OF INDUSTRIAL THERMAL EQUIPMENT			
<b>Code</b>	14540			
<b>Semester</b>	2nd Q(SEMESTER) CONTINUED EVALUATION			
<b>Typology</b>	<b>Degree</b>	<b>Course</b>	<b>Character</b>	<b>Modality</b>
	Master's Degree in Industrial Engineering	2	OPTIONAL	Attendance-based
<b>Course number of credits (ECTS)</b>	6			
<b>Type of activity, credits, and groups</b>	<b>Activity type</b>	PRAULA		TEORIA
	<b>Number of credits</b>	3		3
	<b>Number of groups</b>	1		1
<b>Coordination</b>	DE GRACIA CUESTA, ÁLVARO			
<b>Department</b>	COMPUTER SCIENCE AND INDUSTRIAL ENGINEERING			
<b>Teaching load distribution between lectures and independent student work</b>	60 h lectures (40%) 90 h independent student work (60%)			
<b>Important information on data processing</b>	Consult <a href="#">this link</a> for more information.			
<b>Language</b>	English			
<b>Distribution of credits</b>	Dr. Alvaro de Gracia 3 ECTS Dr. Albert Oriol Castell Casol: 3 ECTS			
<b>Office and hour of attention</b>	To be specified the first day of class.			

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 laboratory 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:

- **Master class:** In master classes the contents are presented orally by the lecturer with no active participation of the students.
- **Problems resolution:** In this activity, the lecturer presents a complex question that the students must solve, either individually or in group.
- **Team work:** Learning activity that must be developed in collaboration with the other members of a team.
- **Laboratory:** It allows to apply and configure, at a practical level, the theoretical knowledge of a specific area in a defined context.

## 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.

Classes on Tuesday from 7 to 9 will be taught by Professor Alvaro de Gracia. Thursdays from 3 to 5 will be taught by Professor Albert Castell.

The chapters given by each teacher are detailed below.

- Chapter 1. Albert Castell / Alvaro de Gracia
- 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. They will be evaluated in the first written test (Week 9, see assessment chapter)

Chapters 4, 5 and 6 will be developed between the weeks 10 and 15. They will be evaluated in the second written test (Week 16-19, see assessment chapter)

## Evaluation

Evaluation activities	%	Dates	C/V (1)	I/G (2)	Observations
PA1: Written exam	20	Week 9	C	I	
PA2: Written exam	20	Week 17	C	I	
PA3: Numerical methods project	25	Week 17	C	G	
PA5: CFD assignment	25	Week 15	C	G	
PA6: Class exercicis and lab practice	10	At proposed dates during course	C	I	
PA7: Recovery exam		Week 19	C	I	Only exams PA1 and PA2 are recoverable

(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. Kreten, 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](http://www.flirmedia.com/MMC/THG/Brochures/T820264/T820264_EN.pdf))

## Adaptations to the development plan due to COVID-19

Project 1 - Numerical modelling development

Project 2 - Combined heat transfer

Project 3 - Conduction project

Project 4 - CFD project

## Adaptations to the evaluation due to COVID-19

Conduction Project 25%

Numerical tool development 30%

CFD project 25%

Combined heat transfer project 20%