UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Course guide
220111 - TT - Heat Technology

Last modified: 19/04/2023

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

Degree: BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Castro Gonzalez, Jesus

Others: Carles David Pérez Segarra
Oliva Llena, Asensio

PRIOR SKILLS

Basic knowledge of previous courses: mathematics (specially differential and integral calculus), physics, mechanics of continuous media, fluid mechanics, thermodynamics.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE20-GRETI. Applied knowledge of thermal engineering. (Specific Technology Module)

TEACHING METHODOLOGY

The preferred language in classes will be Catalan. Spanish is also used.

The different forms of heat transfer are presented sequentially: conduction and radiation, focusing after the analysis on the phenomena of convection. For each of them, we begin with a rigorous approach to the basic equations that describe these phenomena (e.g. Navier-Stokes equations in convection). The deduction and comments of these basic equations are made with special emphasis on the physical meaning of each of the terms. Starting from the basic mathematical formulation, different resolution methodologies (analytical and numerical) are presented. The last module aims to be a synthesis of the previous modules for situations of interest in industrial engineering.

The subject is organized in:
1.- Classes in large groups. In these types of groups, the theory classes, part of the problem classes and the corresponding evaluations are developed. The expository model that the teacher believes most convenient to achieve the objectives that have been set in the subject will be used.
2.- Classes in medium and small groups. In these classes, provided that the availability of teachers allows it, problem sessions are developed by the teacher or those proposed by the students for their resolution and that are part of autonomous learning. Whenever it is considered opportune, some directed activity can be carried out.

The ATENEA platform can be used as a support tool in the two types of classes that have been described. It will be used as a transmitter and communicator with the students.-

LEARNING OBJECTIVES OF THE SUBJECT

Basic formation, in first level, in heat transfer by conduction, convection and radiation: phenomenological aspects, mathematical formulation (basic laws of conservation and constitutive laws) and analytical and numerical solution techniques.
Introduction of technology application issues in order to strengthen basic education and give some initial basis for calculation and design of thermal systems and equipment in order to increase their energy efficiency and reduce environmental impact. Examples are presented related to the fields of heat exchangers, solar, thermal load balance in rooms and buildings, cooling electrical and electronic components.

STUDY LOAD

Type	Hours	Percentage
Hours large group	46,0	30.67
Hours medium group	14,0	9.33
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Module 1. Introduction heat transfer by conduction

Description:
Topic 1. Introduction. Interest and motivation. Description of the basic phenomenologies (conduction, convection, radiation). Examples of industrial and social application.
Topic 2. Heat transfer by conduction. Formulation of the equation of heat transfer by conduction (Equation of energy + Fourier's law) in integral and differential form. Initial and boundary conditions.
Topic 3. Analysis of cases of analytical resolution in permanent regime: heat transfer in plates, cylinders, spheres, compound walls, fins, etc.
Topic 4. Analysis of cases of analytical resolution in transient regime: heat transfer in plates, cylinders and spheres. Extension to the case of two-dimensional and three-dimensional situations.
Item 5. Introduction to numerical methods in heat transfer: basic approach; discretization of the equations; resolution of large systems of algebraic equations; examples of applications in multidimensional situations and transient analysis.

Specific objectives:
Fourier's law, reason it. What is and what does thermal conductivity represent? Deduce - reason the units in which it is given. Relate the heat flux in different spatial directions x and n.
Know and deduce the differential equation of heat conduction in different references (Cartesian, cylindrical, spherical coordinates), in transitory, with variable physical properties, with internal sources...
Understand what Newton's equation of convection is, and its relation to heat conduction in the last layer of fluid in contact with the boundary, ...
Know how to solve conduction in one-dimensional and permanent cases (plates, cylindrical walls, ...), and one-dimensional cases with internal sources (plates, cylinders, bars). Radius concept - critical diameter. Know how to do the exercises/cases carried out in class and those proposed on flat walls, cylindrical, bars ... With "n" layers of materials, with or without internal sources, ...
Understand the theory of fins well, the hypotheses that it entails, the deduction of the differential equation for different fin geometries (rectangular cross-section, cylindrical fins, fins with a variable section in x, ...). Cases of fins with variable physical properties. Recall the ways to consider the boundary conditions in a cantilever fin. Know how to solve those cases of fins that have an analytical solution: fin embedded in two walls that separate three fluids; finned structures formed by crossing fins, ...
Know how to solve transitory problems that have an analytical solution (plates, cylinders - bars, parallelepipeds, finite cylinders). Remember the dimensionless approach of the equations with the Biot and Fourier numbers (it is not necessary to learn formulas by heart) and know how to solve the proposed problems with a numerical solution given to
class.
Know how an ordinary differential equation is solved numerically by Euler's method or similar.
Understand well the numerical methods of finite volumes and finite differences, knowing how to explain them in specific cases (A fin, a rectangular domain, a wall-fin domain, ...) both in permanent and transitory situations and with constant or variable physical properties. You have to know how to discretize the domain, do the balances, and comment on the resolution algorithm. Know the methods of Gauss-Seidel, the TDMA, or Thomas, the Gauss-Seidel supported with the TDMA (line-by-line Gauss-Seidel).

Related activities:
Theory classes, problems and course work.

Full-or-part-time: 40h
Theory classes: 17h
Practical classes: 3h
Self study : 20h

Module 2. Heat transfer by convection

Description:
Topic 6. Introduction. Types of flows and types of convection. Derivation of the basic conservation equations in differential form (Navier-Stokes equations). General statement of the problem and initial and boundary conditions. Brief introduction to the analysis of turbulent flows.
Topic 7. Forced convection. External flows and internal flows in laminar and turbulent regime. Dimensionless analysis: obtaining the characteristic groups. Application exercises.

Specific objectives:
Integral formulation of convection (equations of conservation of mass, amount of movement and energy).
Derivation of the convection equations in differential form (Navier-Stokes equations).
Dimensional analysis. The usefulness of this technique and procedure for obtaining the characteristic groups in cases of forced convection and natural (or free) convection.
Justification of the correlations used to calculate the surface heat transfer coefficients in forced and natural convection.
Methodology for calculating surface heat transfer coefficients. Review cases of forced convection (flow in isothermal plate, external flow in a tube and in a bank of tubes - without and with limiting walls -, flow inside tubes, ...) and natural convection (flow in cavities, free flow in horizontal cylinders, vertical cylinder, vertical plate, ...).

Related activities:
Theory classes, problems and course work.

Full-or-part-time: 38h
Theory classes: 16h
Practical classes: 2h
Self study : 20h

Module 3. Heat transfer by radiation

Description:
Topic 10. Introduction. Basic laws. Derivation of the integral-differential equation of heat transfer by radiation. radiant properties. General statement of the problem and boundary conditions.
Item 11. Heat transfer by radiation in media not involved in radiation. Case of gray and diffuse surfaces: view factors and radiositats method. Application examples.
Item 12. Introduction to heat transfer in media transparent to radiation.

Specific objectives:
Radiation basics: the flow of particles (photons) vs. electromagnetic waves. What is specific radiant intensity and understand its spectral and directional character. Concept of directional and spectral absorptivity, reflectivity, and transmissivity. Black body and its specific radiant intensity. Emissivity concept. Kirchoff's law of radiation.
Usual hypotheses: opaque, gray, and diffuse surface. Medium transparent to radiation. View factor concept, its properties, and its calculation. Examples of their evaluation in three-dimensional situations and in situations
two-dimensional (application of Hottel's theorem). Concept of radiosity and irradiation. The formulation for gray and diffuse surfaces (avoid learning the formulas by heart, it is very important that the physical concept of each term is clear). Evaluation of the net heat of radiation. Application to the resolution of diverse problems.

Related activities:
Theory classes, problems, and coursework.

Full-or-part-time: 22h
Theory classes: 8h
Practical classes: 2h
Self study : 12h

Module 4. Combined Problems

Description:
Subject 13. Problems that appear in a combined way mechanisms of heat transfer by conduction, convection and radiation. Carrying out exercises with possible application to fields of industrial interest (heat exchangers, active systems for harnessing solar energy - solar collectors -; passive systems for harnessing solar energy; balance of thermal loads in rooms and buildings, etc.)

Specific objectives:
Combined problems (conduction + convection + radiation). Very important the cases carried out in class: a composite vertical wall that separates two fluids; double tube exchanger; greenhouse; ... Pay attention to the different levels of simulation (analytical, one-dimensional or multi-dimensional numerical, permanent or transient formulation, etc.).
In the case of resolution using analytical methods, pay attention to the formulation of the equations and the resolution algorithms of the resulting system of equations.
In the case of numerical resolution and the treatment of fluids, the section-by-section method must be taken into account for obtaining the map of velocities, pressures, and temperatures. The driving analysis is performed using finite volume techniques and according to the explanations made in the driving topic. The formulation of
the radiation will be done according to the radiosity method.
Once the discrete equations have been written and the empirical coefficients (coefficients of heat transfer and friction) and view factors have been evaluated, it is necessary to be clear about the resolution of the system of discrete equations that are obtained based on the algorithms' resolution costs explained by both permanent and transitory cases.

Related activities:
Theory classes, problems, and coursework.

Full-or-part-time: 51h
Theory classes: 5h
Practical classes: 8h
Self study : 38h

ACTIVITIES

THEORY LESSONS

Description:
Large group methodology.
Exposition of the contents of the subject following an expository and participatory class model.
The subject matter has been organized into 4 thematic areas or themes.
In this class problems are solved with the whole group

Specific objectives:
At the end of this activity, the student should be able to master the knowledge acquired, consolidate it and apply it correctly to different technical problems. In addition, being Thermotechnics a techno-scientific subject, the theory classes must serve as a basis for the development of other more technical subjects in the thermal field related to Thermotechnics, such as Refrigeration, Thermal Engines or Solar Energy.

Material:
Basic bibliography.
Teacher's notes (reprography and/or Athena).

Delivery:
This activity is evaluated jointly with activity 2 (problems) through a first partial exam and a second final exam.

Full-or-part-time: 65h
Theory classes: 25h
Self study: 40h

PROBLEM LESSONS

Full-or-part-time: 75h
Theory classes: 21h
Practical classes: 14h
Self study: 40h

PROJECTO OF THE COURSE

Full-or-part-time: 10h
Self study: 10h

GRADING SYSTEM

The mid-term exam accounts for 40% of the final grade.
The control test accounts for 10% of the final grade.
The final exam accounts for 50% of the final grade.
If the mark of the partial exam is less than 5, there will be the possibility of improving this mark at the end of the course in a written test. The mark of the re-evaluation will substitute the previous one as long as it is higher, with a maximum of 5 points. This exam will be held on the day set in the academic calendar for the final exam.
The successful presentation and defense of the voluntary numerical work carried out during the course will increase the final grade obtained by the student as long as it is higher than 5.

EXAMINATION RULES.

The exams will consist of theory and problems. It is not allowed to use any extra material, except the one delivered by the lecturers. The use of mobile phones, smartwatches or similar devices, together with computers and programmable calculators, is also not allowed.

BIBLIOGRAPHY

Basic:
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- Isachenko, V. P.; Osipova, V.; Sukomel, A. Transmisión de calor. Barcelona: Marcombo-Boixareu, 1973. ISBN 8426702392.
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- Kreith, F.; Bohn, M. S. Principios de transferencia de calor. 6ª ed. Madrid: International Thomson, 2002. ISBN 8497320611.
- Lienhard IV, J. H.; Lienhard V, J. H. A heat transfer textbook [on line]. 3rd ed. Cambridge: Phlogiston Press, 2003 [Consultation: 14/05/2020]. Available on: http://web.mit.edu/lienhard/www/ahtt.html.
- Çengel, Y.A. Heat and mass transfer: a practical approach. 3rd ed. Boston: McGraw-Hill, 2007. ISBN 0073129305.
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Complementary:
- Wong, H. Y. Handbook of essential formulae and data on heat transfer for engineers. New York: Longman, 1977. ISBN 0582460506.
- Rohsenow, W. M.; Hartnett, J. P.; Cho, Y. I. Handbook of heat transfer. 3rd ed. New York: McGraw-Hill, 1998. ISBN 0070535558.
- Eckert, E. R. G.; Drake, R. M. Heat and mass transfer. 2nd ed. New York: McGraw-Hill, 1959.
- Patankar, S. V. Numerical heat transfer and fluid flow [on line]. New York: McGraw-Hill, 1980 [Consultation: 16/11/2022]. Available on: https://www-taylorfrancis-com.recursos.biblioteca.upc.edu/books/mono/10.1201/9781482234213/numerical-heat-transfer-fluid-flow-suhas-patankar. ISBN 9780891165224.

RESOURCES

Audiovisual material:
- Apunts realitzats pel professorat de l'assignatura

Other resources:
Notes made by the teachers of the subject.