Universidade Vigo

IDENTIFYING DATA				
Thermodynamics and heat transfer				
Subject	Thermodynamics and heat transfer			
Code	P52G381V01203			
Study programme	Grado en Ingeniería Mecánica			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	2nd	1st
Teaching language	Spanish			
Department				
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General description	The aim of this subject is to train future graduates in Bachelor Degree in Mechanical Engineering with the ability to apply the principles of Thermodynamics and Heat Transfer required in almost all industrial processes and domestic installations. The knowledge of these principles is basic in Thermal Engineering, for instance, to carry out an energy analysis (determining the energy and exergy efficiency) of power systems for electricity generation (combined cycle with steam and gas turbine), a mechanical power cycle, a heat pump cycle, etc. The knowledge of whether a thermodynamic process can occur in reality is essential for the design of new processes, as well as the knowledge of the maximum benefits that can be obtained by the different devices present in an energy installation, and the causes hindering those maximum benefits. Furthermore, the study of the thermodynamic properties of the working fluids that circulate through the devices, water, air, refrigerants, gases and gas mixtures, is essential to analyse the behaviour of thermal systems. Likewise, studying the procedure needed for the energy analysis of refrigeration, air conditioning and in combustion processes is of great interest. On the other hand, it is essential for students to know the heat transfer mechanisms, focusing on determining the way and rate of the energy exchanged. Thus, at the end of the course, students are expected to be able to properly state and solve heat transfer engineering problems and to perform a basic design of heat exchangers.			

Skills	
Code	
B4	Ability to solve problems with initiative, decision making, creativity, critical thinking and the ability to communicate and transmit knowledge and skills in the field of Industrial Engineering in Mechanical specialty.
B5	Knowledge to carry out measurements, calculations, assessments, appraisals, surveys, studies, reports, work plans and other similar works.
B6	Capacity for handling specifications, regulations and mandatory standards.
B7	Ability to analyze and assess the social and environmental impact of the technical solutions.
B11	Knowledge, understanding and ability to apply the necessary legislation in the exercise of the profession of Industrial Technical Engineer.
C7	Knowledge of applied thermodynamics and heat transfer. Basic principles and their application to solving engineering problems.
D2	Problems resolution.
D7	Ability to organize and plan.
D9	Apply knowledge.
D10	Self learning and work.
D17	Working as a team.

Learning outcomes	
Expected results from this subject	Training and Learning Results

Capacity to know, understand and use the principles and fundamentals of applied thermodynamics	B4 B5 B6 B7	C7	D2 D7 D9 D10 D17
Ability to know and understand the principles and fundamentals of heat transmission	B5 B6 B7 B11	C7	D2 D7 D9 D10 D17
Ability to know and understand the principles and fundamentals of thermal equipment and generators	B4 B6 B7 B11	C7	D2 D7 D9 D10 D17
Analyze the operation of thermal systems, such as heat pump systems, refrigeration cycles or power cycles, identifying components, as well as the cycles used to obtain high performance.	B4 B5 B6 B7 B11	C7	D2 D7 D9 D17
ENAEE learning outcome: KNOWLEDGE and UNDERSTANDING: LO1.2.- Knowledge and understanding of the mathematics and other basic sciences underlying their engineering specialisation, at a level necessary to achieve the other programme outcomes [Level of achievement (Basic (1), Intermediate (2) and Advanced (3)) for this learning outcome: [Advanced (3)].		C7	
ENAEE learning outcome: ENGINEERING ANALYSIS: LO2.2.- Ability to identify, formulate and solve engineering problems in their field of study; to select and apply relevant methods from established analytical, computational and experimental methods; to recognise the importance of non-technical - societal, health and safety, environmental, economic and industrial - constraints [Advanced (3)].	B4 B7		D2 D9
ENAEE learning outcome: RESEARCH AND INNOVATION: LO4.1.- Ability to conduct searches of literature, to consult and to critically use scientific databases and other appropriate sources of information, to carry out simulation and analysis in order to pursue detailed investigations and research of technical issues in their field of study. [Basic (1)].	B6 B11		
ENAEE learning outcome: RESEARCH AND INNOVATION: LO4.2.- Ability to consult and apply codes of practice and safety regulations in their field of study [Basic (1)].	B6 B7 B11		
ENAEE learning outcome: RESEARCHING AND INNOVATION: LO4.3.- Ability to design and conduct experiments, interpret data and draw conclusions [Intermediate (2)].		C7	D9
ENAEE learning outcome: ENGINEERING PRACTICE LO5.4.- Ability to apply norms of engineering practice in their field of study [Basic (1)].	B6 B7 B11		D9
ENAEE learning outcome: ENGINEERING PRACTICE LO5.5- Awareness of non-technical -societal, health and safety, environmental, economic and industrial □ implications of engineering practice [Basic (1)].	B7		
ENAEE learning outcome: MAKING JUDGEMENTS LO6.1.- Ability to gather and interpret relevant data and handle complex concepts within their field of study, to make judgements that involve reflection on ethical and social issues [Basic (1)].	B6 B7 B11		

Contents
Topic

BLOCK 1 (B1): Properties of pure, simple and compressible substances	B1-1. Review of basic concepts and definitions - Systems definition - Description of the systems and their behaviour - Temperature measurement. Zero Law of Thermodynamics - Heat and specific heat - Phase change and latent heat - Ideal gas. State equations - The First Law of Thermodynamics - Thermodynamic transformations of an ideal gas - The Second Law of Thermodynamics B1-2. Properties of a pure, simple and compressible substance - Definition of the thermodynamic state - The p-v-T relationship - Calculation of thermodynamic properties - The ideal gas model - Internal energy, enthalpy and specific heats of ideal gases - Calculation of internal energy and enthalpy changes in ideal gases - Polytropic processes of an ideal gas
BLOCK 2 (B2): Energy analysis of systems according to the First and Second Law	B2-1. Energy analysis of control volumes - Conservation of mass - Conservation of energy - Steady state analysis - Transient analysis B2-2. The Second Law of Thermodynamics - Using the 2nd law - Formulations of the 2nd law - Identification of irreversibilities - Application of the 2nd low to thermodynamic cycles - The Kelvin temperature scale - Maximum efficiency measurements for cycles operating between two heat sources - The Carnot cycle B2-3. Entropy and its use - Clausius inequality - Definition of entropy change - Obtaining entropy values - Entropy change in internally reversible processes - Entropy balance for closed systems - Entropy balance for control volumes - Isentropic processes - Isentropic efficiencies of turbines, nozzles, compressors and pumps B2-4. Exergy analysis - Definition of exergy - Exergy balances - Exergy efficiency (second law)
BLOCK 3 (B3): Introduction to thermodynamic analysis of thermal motors and machines	B3-1. Power production facilities - Introduction to power production facilities - Vapor power production: the Rankine Cycle - Gas turbine power production facilities: the Brayton cycle - Combined cycle B3-2. Gas cycles in reciprocating internal combustion engines - Otto cycle - Diesel cycle B3-3. Refrigeration cycles - Refrigerators - Heat pumps

BLOCK 4 (B4): Fundamental concepts and principles in heat transfer	B4-1. Introduction to heat transfer - Fundamental concepts in heat transfer - Mechanisms of heat transfer: conduction, convection and radiation - Fourier's law. Thermal conductivity and diffusivity - Newton's law of cooling. Convection coefficient - Stefan-Boltzmann law. Emissivity and absorptivity B4-2. Heat transfer by conduction - General heat conduction equation - One-dimensional conduction in steady state. Plane walls - Thermal resistance. Thermal resistance network - Global heat transfer coefficient - Stationary conduction with thermal energy generation - Conduction in radial systems: cylinders and spheres B4-3. Heat exchangers - General considerations - Classification of heat exchangers. Characteristics and selection criteria - Parallel, countercurrent and cross flow temperature distribution - Considerations for the design of heat exchangers - Heat flow exchanged - Logarithmic mean temperature difference (DTML) method - Efficiency method-number of transfer units (E-NUT) B4-4. Heat transfer by convection - Movement of a fluid. Laminar and turbulent flows - Boundary layers of convection: hydraulic and thermal - Dimensionless numbers - Free and forced convection - Empirical correlations for external and internal flows B4-5. Heat transfer by radiation: general principles - Fundamental concepts. Electromagnetic spectrum. Thermal radiation - Blackbody radiation. Planck's Law. Wien's Law - Definitions: radiation intensity, irradiance, emissivity - Surface absorptivity, reflectivity and transmissivity - Kirchhoff's Law

PRACTICAL CONTENTS	The seven practices proposed aim to consolidate and deepen the knowledge acquired in the theoretical classes while developing research skills: design of experiments, analysis and collection of experimental data, discussion of results using appropriate sources of information, etc. PL 1. Mechanical equivalent of heat This practice aims to determine the mechanical equivalent of heat, that is, the relationship between the energy unit (Joule) and the heat unit (calorie). Through this practical experience, it is highlighted the large amount of mechanical energy that needs to be transformed into heat to significantly increase the temperature of a small mass. PL 2. Linear thermal expansion of solids Study of linear thermal expansion in iron, brass and aluminum thin tubes. Estimation and comparison of the coefficients of expansion of these materials. The implications of the materials expansion on structural safety will be evaluated, as stated in the Technical Building Code (CTE). PL 3. Introduction to thermographic techniques It is intended to initiate students in the use of thermographic cameras as a tool applied to the study of insulation in buildings and predictive maintenance. The environmental implications of their use will be analysed. The importance of emissivity in this technique will be studied. PL 4. Thermal conductivity of metals It will be determined the heat flux that occurs through U-shaped metal bars whose ends are immersed in hot and cold water. It will be proved that the heat flux depends on the composition of the material, as well as its cross section and length. PL 5. Determination of insulation properties It is intended to observe the thermal properties of different insulating materials for the management and understanding of concepts such as thermal insulation, thermal conductivity and heat capacity. PL 6. Heat exchanger The aim is to better understand the operation of heat exchangers, establish energy balances and determine the effectiveness and the integral coefficient of heat transfer as a function of the direction and flow of the fluids. Likewise, the DTLM and ε-NUT methods will be validated and the dimensionless numbers will be applied to estimate the theoretical heat transfer coefficients. PL 7. Alternative energies. Study of a solar collector. It is intended to initiate students in the study of a solar collector, analyse the energy received by radiation and make an energy balance of the energy used for domestic hot water, thus being able to meet the requirements of the CTE. Different configurations of the equipment will be tested in order to understand its operation and find the one that maximizes energy use.

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	28	37	65
Laboratory practical	14	7	21
Problem solving	7	7	14
Seminars	15	12	27
Problem and/or exercise solving	0	4	4
Objective questions exam	4	4	8
Essay questions exam	3	2	5
Essay questions exam	6	0	6

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description

Lecturing	Teaching in the classroom of the key concepts and procedures for learning the syllabus contents. In addition to the information published on the online teaching platform Moovi, which contains the file with the lesson slides, the students have in the recommended bibliography the contents of each leasson with a more detailed development.
Laboratory practical	Application of the knowledge acquired in the lectures to the resolution of practical problems. A series of practices have been designed in accordance with the content of the subject in order to fix the explained concepts, so that the the student develops his creativity and his ability to propose technical solutions
Problem solving	The student must solve exercises and problems related to the subject individually.
Seminars	Intensive 15-hour course for those students who have failed the subject on the first call, prior to the exam on the second call. The lecturer briefly reviews theoretical concepts of the subject and proposes problems to be solved, while individually supervising the work of each student. An active learning methodology is promoted.

Personalized assistance

Methodologies	Description
Lecturing	Assistance in groups of approximately 40 students. To complement the personalized assistance, a tutorial action will be carried out. In the scope of the tutorial action, it can be distinguished between academic tutoring actions (in group or individually) and personalized tutoring. Both types of tutorial action are combined to compensate for the different learning rhythms and thus paying attention to diversity. The lecturers of the subject will solve the questions and queries of the students in person or online (via email, videoconference, Moovi forums, etc.) at the time scheduled on the website of the center or by appointment.
Laboratory practical	Assistance in groups of 20 students. It is complemented with academic and personalized tutoring.
Problem solving	Assistance in groups of 10 students. It is complemented with academic and personalized tutoring.
Seminars	Continuous tutorng action, with constant support by the lecturer to the student's learning process. Students receive personalized assistance in small groups. It is complemented with academic and personalized tutoring.

Assessment

	Description	Qualification	Training and Learning Results		
Laboratory practical	The assessment will be carried out through deliverables and a questionnaire (ECP). The questionnaire will be loaded in Moovi and it will assess the knowledge acquired in the lectures and in the laboratory related to the practices. On the other hand, the deliverables of each practice evaluate the quality of the experimental data collection, the understanding of the practice, synthesis capacity, logical reasoning, teamwork and the search for appropriate sources of information that help to understand the problem under study and to contrast the results obtained. The mark of each deliverable and the questionnaire will be out of 10 points. The global grade of practices will be the average of the mark of all the deliverables and the questionnaire.	20	B4 B5 B6 B7 B11	C7	D2 D7 D9 D10 D17
Problem and/or exercise solving	During the semester different tasks (TE) will be proposed, some will be individual and others may be in group. The objective of these tasks will be to promote the understanding of the theoretical/practical contents and to delve into other key aspects of the subject, such as the management and application of regulations such as the Technical Building Code in matters of energy saving. These activities will be compulsory and scored, each one of them, out of 10 points.	10	B4 B5 B6 B7 B11	C7	D2 D7 D9 D10 D17
Objective questions exam	Mid-term exams (PP) Their objective is to evaluate the theoretical contents and the ability to solve problems acquired during part of subject, since two mid-term exams will be conducted (weighting 15% each). These tests will consist of a series of questions and exercises that prioritize conceptual and logical reasoning, in order to verify the intellectual maturity of the students to obtain conclusions from contents presented in lectures. Both test will be compulsory and scored on 10 points each.	30	B4 B5 B7 B11	C7	D2 D7 D9 D10

Essay questions exam	Final Exam (EF) Its objective is to evaluate the theoretical contents and the ability to solve problems acquired during the whole subject in the lectures and seminars. This test will consist of a series of questions and exercises that prioritize conceptual and logical reasoning, in order to verify the intellectual maturity of the students to obtain conclusions from contents presented in lectures. This test will be compulsory and scored on 10 points.	40	B4 B5 B7 B11 C7 D2 D7 D9 D10
Essay questions exam	Ordinary and Extraordinary Exam If the students do not pass the continuous evaluation, they will have an ordinary exam after the final exam. In this exam the students will be evaluated of all the contents taught in the lectures, seminars and practical sessions. This exam will represent 100% of the final grade of the student. It will be necessary to obtain a grade higher than 5 points out of 10 to pass the exam. If the students do not pass the ordinary exam, they would go directly to the second call in July. In the extraordinary exam the student will be examined of all the theoretical/practical contents taught in the subject during the ordinary course.	100	B4 B5 B6 B7 B11 C7 D2 D7 D9 D10

Other comments on the Evaluation

Sources of information

Basic Bibliography

Çengel, Yunus y Boles, Michael, **Termodinámica**, 9ª, McGraw-Hill, 2019

Moran M.J. y Shapiro H.N., **Fundamentos de Termodinámica Técnica**, 2ª, Reverté, 2015

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Complementary Bibliography

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Haywood R.W, **Ciclos termodinámicos de potencia y refrigeración**, Limusa, 2000

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Segura, J, **Termodinámica Técnica**, Reverté, 1988

Baehr, H. D, **Tratado moderno de termodinámica**, Tecnilibro, S.L, 1987

Holman, J. P, **Transferencia de Calor**, 8ª, Mc Graw-Hill, 1998

Agüera Soriano, J, **Termodinámica Lógica y Motores Térmicos**, Ciencia 3, S.A.,

Alarcón Aguín, J. M.; Granada Álvarez, E.; Vázquez Alfaya, M. E., **SISCECT, Simulación y cálculo de ciclos termodinámicos**, Bellisco, 1999

Chapman A.J., **Transmisión de calor**, 3ª, Bellisco, 1990

Lienhard IV J.H., Lienhard V J.H., A, **A heat transfer textbook**, Phlogiston Press, 2005

Segura J., y Rodriguez J, **Problemas de Termodinámica Técnica**, Reverté, 1993

Lacalle, Nieto, **Problemas de Termodinámica Técnica**, 3ª, Dextra, 2017

Corrochano Sánchez, C.; Muñoz Antón, J,; Ortiz Gómez, A.; Fernández Benítez, J.A., **Problemas de transferencia de calor**, Dextra, 2014

Recommendations

Subjects that continue the syllabus

Thermal engineering I/P52G381V01403

Other comments

To successfully complete this subject, the student must have the following skills:
- Written and oral comprehension.
- Abstraction, basic calculation and synthesis of information.