UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
220098 - TD - Thermodynamics

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

LECTURER

Coordinating lecturer: Yolanda Calventus

Others: Joaquim Rigola, Frida Roman, Carles Oliet, Santiago Torras, Nicolás Ablanque

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE07-INDUS. Knowledge of applied thermodynamics and heat transfer. Basic principles and their application to solving engineering problems. (Common module for industrial engineering)

Transversal:
CT05 N2. Effective use of information resources - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.

TEACHING METHODOLOGY

The course is organized into:
1. Lessons in large groups. In this group theory classes are developed, classes of problems and assessments on the 1st and 2nd partial.
2. Two. - Lessons in middle groups. In these classes will be developed problem solving sessions by the teacher, or the problems proposed to the students resolution and are part of autonomous learning. Whenever deemed necessary may be do some directed activity.
3. Three. - Classes in small groups: This activity develops laboratory practices and generic competition CG6 "Solvent use information resources."

Athenea platform can be used as a tool to support both types of classes that have been described. Used as a transmitter and communicating with students.

LEARNING OBJECTIVES OF THE SUBJECT

Learning objectives of the course
· Acquire a basis for future studies of heat transfer, Fluid Mechanics and Heat Engines through a rigorous and comprehensive treatment of classical thermodynamics following a methodology
· Acquire the capacity to apply thermodynamics in subjects related
· Acquire the ability to make simplifying assumptions of thermodynamic problems based on real processes
· Acquire skills in handling instrumentation used in the laboratory.
· Relate and apply theoretical concepts to solve problems at the labs.
· Improving the use of quantities and units, tables and equations for the determination of physical quantities
· Acquire capacity for efficient use of the literature.

STUDY LOAD

Type	Hours	Percentage
Hours small group	14,0	9.33
Hours large group	32,0	21.33
Hours medium group	14,0	9.33
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Content 1: Accurate concept of thermodynamic approach

Description:
1.- Previous concepts on the approach of Thermodynamics
1.1 .- Objectives and method of the classical thermodynamics of equilibrium. 1.2.- Thermodynamic system and types of systems. 1.3 .- State of a system and state variables. State postulate 1.4.-Equations of state. 1.5.- Thermodynamic equilibrium. 1.6.- Processes in thermodynamic systems. Quasi-static, reversible and irreversible processes. 1.7.-Cyclic processes. 1.8.- Thermal coefficients: isothermal compressibility, isobaric expansion and piezothermal.

Specific objectives:
- Identify the specific vocabulary related to Thermodynamics through the precise definition of basic concepts to feel the language of Thermodynamics. Master the concepts of: system, border, environment, state, state variables, independent variable, thermodynamic equilibrium, process ¿
-To know how to classify a system according to its walls, know how to find its independent variables.
- Define the concept of state equation and state thermal equation.
- Define the concepts of coefficient of expansion, compressibility, piezo-thermal, its sign, its dependence on the thermodynamic variables, units and the relationship between them.
- Calculate variations in temperature, pressure, volume and find the thermal equation of state from the coefficients. Thermals

Related activities:
Theroy and problems classes and lab sessions

Full-or-part-time: 13h
Theory classes: 4h
Practical classes: 1h
Laboratory classes: 2h
Self study : 6h

Content 2: Volumetric Properties of a pure substance, simple and compressible

Description:
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Related activities:
- Theory and problems classes and lab sessions
Activity: Quizz about contents 1 and 2

Full-or-part-time: 27h
Theory classes: 5h
Practical classes: 2h
Laboratory classes: 2h
Self study : 18h

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Content 3: First law of thermodynamics

Description:
3.1.- The First Principle of Thermodynamics in closed systems
3.1.1.-Energy interactions. 3.1.2.- Work in Thermodynamics. 3.1.3.- Definition of heat. 3.1.4.-Formulation of the First Principle in closed systems. 3.1.5.-Energy analysis of a cycle. 3.1.6.-Enthalpy function. 3.1.7.-Thermal effects. Heat capacity at constant volume and constant pressure. Mayer's relationship. 3.1.8.- Variations of internal energy and enthalpy in ideal gases. 3.1.9.- Definition of perfect gas. 3.1.10.- Model of incompressible substance. 3.1.11.- Latent heat of transformation or phase change. Clapeyron equation 3.1.12.- Sensitive heat. 3.1.13.- Free expansion of a gas in a vacuum. 3.1.14.-Adiabatic processes: PvT equations for perfect gas reversible adiabatic processes. 3.1.15.- Polytopic processes.
3.2.-The first principle of Thermodynamics in open systems.
3.2.1.- Definition of continuous system and volume of control. 3.2.2.- Conservation of mass and energy in a control volume. 3.2.3.- Development of the term work. 3.2.2.- Balance of mass and energy in a control volume. 3.2.5.- Processes with perfect gases in open systems of stationary flow.
3.3.- Application of energy analysis to control volumes.
3.3.1.- Description of stationary flow devices

Specific objectives:
- Define the concept of thermodynamic work and apply it to any thermodynamic system
- Formulate the first principle of Thermodynamics as a statement of the principle of conservation of energy for closed systems (mass of control)
- Define the concept of heat
- Define the specific heat at constant pressure and volume and relate them to the calculation of the internal energy and enthalpy of an ideal gas.
- Define perfect gas
- Understand the equations of the reversible adiabatic of a perfect gas and of the polytropic processes.
- Solve energy balance problems in closed systems.
- Know how to deduce the equations of conservation of mass and energy in a control volume
- Interpret each one of the terms that appear in it. Develop the term work
- Define steady state
- Formulate the equations of conservation of mass and energy in a volume of control in a stationary flow
- Describe the processes of perfect gases in open systems of stationary flow

Related activities:
Theory classes, problems and laboratory practices.
1st partial exam. Contents 1, 2 and 3 (teachers must confirm)

Full-or-part-time: 50h
Theory classes: 10h
Practical classes: 5h
Laboratory classes: 5h
Self study : 30h

Content 4: Second law of thermodynamics

Description:
4.1.- Introduction to the Second Principle of Thermodynamics
4.1.1.- Limitations of the First Principle. 4.1.2.- Classical statements of the Second Principle. 4.1.3.- Thermal machines. Performance. 4.1.4.-Refrigeration machines and heat pumps. Efficiency coefficients. 4.1.5.-Reversible and irreversible processes. 4.1.6.-Carnot cycles. Carnot corollaries. 4.1.7.- Formulation of the performance and the efficiency coefficient according to the temperatures of the foci. 4.1.8.- Concept of temperature. Thermodynamic temperature scale.
4.2.- Entropy. Entropy balance.
4.2.1.- Clusius inequality.4.2.2.- Entropy concept. 4.2.3.- Equations Tds. 4.2.4.- Calculation of entropy variations. 4.2.5.- Entropy of a pure, simple and compressible substance. Tabulated data of entropy. 4.2.6.-Entropic diagrams: h-s and T-s. 4.2.7.-Principle of increasing entropy. 4.2.8.-Thermal entropy flow and entropy production. 4.2.9.-Sources of irreversibilities. 4.2.10.- Production of entropy and degradation of energy. 4.2.11.- Entropy balance in closed systems and control volumes.
4.3 .- The Second Principle applied to devices in adiabatic stationary flow. Isentropic performance.
4.3.1.-Isentropic process. 4.3.2.- Isentropic performance of some stationary flow devices: turbines, compressors, nozzles, diffusers and pumps. 4.3.3.- Comparison between reversible and irreversible work interactions in turbines, compressors and pumps.

Specific objectives:
Identify the limitations of the First Principle
Remember the classical statements of the Second Principle of Thermodynamics. Define heat focus
Define reversible and irreversible process
Define the concept of thermal performance and COP
Analyze direct heat machines and refrigerators and heat pumps.
Give examples of thermodynamic cycles such as Rankine, Brayton, and cooling cycles.
Describe the Carnot cycle
Remember and demonstrate the Carnot corollaries
Deduce and interpret Clausius inequality
Define the concept of entropy from Clausius inequality.
Formulate equations for the calculation of entropy variations of ideal and perfect gases, incompressible substances, phase changes, heat sources
Calculate entropy and entropy variations with the equations in the previous section and using the tables.
Describe T-s and h-s diagrams and represent processes and cycles
Formulate the principle of increasing entropy
Formulate the entropy balance in a closed system. Interpret the terms that appear in the equation.
Classify irreversibilities and give examples
Deduce the entropy balance equation in control volumes
Apply entropy balance equations to closed systems and control volumes to solve problems
Define a special class of idealized processes called isentropic.
Compare isentropic processes with real (irreversible adiabatic) processes using real work and isentropic work.
Define the isentropic performance of an expansion and a compression.

Related activities:
- Theory and problem classes and laboratory sessions
- Activity: Quizz about thermal engines and the second law applied to closed systems

Full-or-part-time: 47h
Theory classes: 9h
Practical classes: 5h
Laboratory classes: 5h
Self study : 28h

Content 5: Thermodynamic cycles

Description:
5.1.- Power cycles.
5.1.1.- Basic Rankine cycle. 5.1.2.-Applications of the Rankine cycle. 5.1.3.-Simple Brayton cycle. 5.1.4.- Applications of the Brayton cycle.
5.2.- Refrigeration cycles.
5.2.1.- Steam compression cycles (reverse Rankine). Applications

Specific objectives:
Recognize the basics elements of the Rankine cycle
Recognize the basics of a simple Brayton cycle
Give examples of applications from both cycles
Perform the energy analysis of these cycles
Recognize the basic elements of a steam compression cooling cycle

Related activities:
Theory and problems classes and laboratoy sessions

Final exam: all the contents done in the subject

Full-or-part-time: 13h
Theory classes: 4h
Practical classes: 1h
Self study : 8h

ACTIVITIES

1. THEORY LESSONS

Description:
Methodology in large group
Presentation of the contents of the subject following a model of participatory and expository class.
The subject matter has been organized into 5 thematic areas or topics.
This class will solve problems with the whole group.

Specific objectives:
At the end of this activity, the student must be able to master the acquired knowledge, consolidate and apply it correctly to technical problems that involve real situations. In addition, they must be the basis for the development of other subjects in the field of Thermodynamics related to Heat Transfer, Heat Engines and Refrigeration.

Material:
Basic bibliography
Teacher's notes (ATENEA).
Pure fluid thermodynamic properties table book.
Pure fluid properties diagrams: T-s, h-s and P-h.

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

Full-or-part-time: 68h
Theory classes: 26h
Self study: 42h

2. PROBLEM LESSONS

Description:
Medium group methodology
In each of the topics, there will be problems in class so that students acquire the necessary guidelines to carry out this resolution: approach, numerical resolution, simplifications, units, ...

Specific objectives:
At the end of this activity, the student should be able to apply theoretical knowledge to solving real technical problems. From a strictly methodological point of view, the student must be able to: 1.- Understand the statement and analyze the problem. 2.- Propose and develop a work plan to solve the problem. 3.-Propose the possible ways to arrive at the planned solution based on the data. 4.- Solve the problem using the necessary equations, following the rules and instructions on units, signs and significant figures. 5.- Interpret the answer and see if it is logical, both numerically and in units.

Material:
Basic bibliography
Teacher's notes (ATENEA).
Pure fluid thermodynamic properties table book.
Pure fluid properties diagrams: T-s, h-s and P-h.

Delivery:
This activity is evaluated in conjunction with activity 1 (theory) by means of a partial exam and a final exam.

Full-or-part-time: 40h
Practical classes: 14h
Self study: 26h

3. LABORATORY PRACTICE

Description:
This activity consists of performing 6 laboratory practices plus two exhibition sessions of two of the practices performed.
The practices will be performed in groups of two students in the Thermodynamics laboratory.
The structure to be followed will be:
1.- Preparation of the practice through the manual of practices.
2.- Practice in groups of 2 students. The maximum duration will be 2 hours.
3.- Discussion of the results obtained and the problems that have arisen during the realization of the practice.
4.- Writing a report on the practice made with experimental results, graphical constructions, questions and conclusions. This report will be evaluated along with the completion of the practice.
5.- Oral presentation of two of the practices performed. This exhibition will be evaluated in terms of objectives, methodology, results, conclusions and questions raised at the end of the exhibition. The maximum duration is 15 minutes.

Specific objectives:
At the end of this activity, the student should be able to: a) Know how to describe the experimental tasks performed; b) Process the experimental data obtained and draw conclusions; c) Correctly prepare the report of the work done; d) Know how to present this report correctly, clearly and in a timely manner, and correctly answer the questions that arise.

Material:
Laboratory material
Equipment and assemblies appropriate to the objectives of the practice.
Practice scripts and reports to be submitted.

Full-or-part-time: 36h
Laboratory classes: 14h
Self study: 22h

4. 1 MIDTERM EXAM

Description:
Development of the partial exam of the subject.
It includes theoretical aspects and problem development.
This partial does not eliminate matter

Specific objectives:
Show the level of knowledge reached in the theoretical and problem activities.

Material:
Book of charts and graphs of thermodynamic properties.
The use of a formula sheet, whose characteristics will be indicated by the teaching staff, is allowed.

Delivery:
The exam is resolved on the fold of sheets delivered at the beginning of the test by the theoretical part and / or on additional sheets due to the problems. The extra sheets, if any, are attached to the theory sheets at the end of the test.
At the beginning of the test will indicate the score of each exercise, theory and problems, and the evaluation criteria.
The rating of this activity N1P is worth 30% of the final overall rating.
This first partial does not eliminate matter.

Full-or-part-time: 2h
Theory classes: 2h

5. 2 FINAL EXAM

Specific objectives:
Show the level of knowledge reached in the theoretical and problem activities.

Material:
Book of charts and graphs of thermodynamic properties.
The formula sheet is allowed (Teacher will indicate how the formula sheet must be)

Delivery:
The exam is resolved on the fold of sheets delivered at the beginning of the test by the theoretical part and / or on additional sheets due to the problems. The extra sheets, if any, are attached to the theory sheets at the end of the test.
At the beginning of the test will indicate the score of each exercise, theory and problems, and the evaluation criteria.
The rating of this activity N2P is worth 40% of the final overall rating.

Full-or-part-time: 2h
Theory classes: 2h

6. MID-TERM LEVEL TESTS

Description:
Development of a partial level test of the syllabus already studied.
During the course there will be 2 evaluable level tests

Specific objectives:
Show the level of knowledge reached in the theoretical and problem activities.

Material:
Book of charts and graphs of thermodynamic properties.
It is allowed to use a formula sheet

Delivery:
The test is settled on the sheet of paper delivered at the beginning.
At the beginning of the test the score of each exercise and the evaluation criterion will be indicated.
The average rating of the 2 level tests, Nc, will be equivalent to 15% of the final overall rating.

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

- 1st Midterm Exam: 30%
- 2nd Midterm Exam: 40%
- Laboratory work: 15%
- Level Tests: 15%

The course will provide for procedures to recover unsatisfactory results obtained in the first evaluation, inside the final exam (for students with a mark lower than 5 with a degree between 0 and 5).

EXAMINATION RULES.

1. - Activity 3 (laboratory practice), any lack of assisstence it is equivalent to a score of zero in the practice without the possibility of recovery. The lack of punctuality at the beginning of the session (maximum 15 minutes) imply the no realization of the practice without the possibility of recovery. The report of internship can be made in group or individual and will be given to the next practice session. If a student has not attended a practice session will not sign the report made by their peers. The exhibition will do in groups, using the appropriate resources, and delivering a copy of the material used at the end of the exhibition. Students who do not attend the session will obtein a rating of zero.

2. - The first midterm exam (activity 4), the second midterm exam (activity 5) and the level tests (activity 6) will be without the use of books, notes or other teaching materials, except tables, graphs and a form. You can't use a calculator that can be programmed and any mobile device even when not connected.
The students have to identify themself by ID or student card.

4.-The 3 activity will also value generic competition assigned (CG6: effective use of information resources)

BIBLIOGRAPHY

Basic:

- Çengel, Yunus A.; Boles, Michael A. Termodinámica [on line]. 9ª ed. México: McGraw-Hill, 2019 [Consultation: 03/10/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=5808940. ISBN 9781456269166.
- Moran, Michael J. [et al.]. Fundamentos de termodinámica. 2a ed. Barcelona: Reverté, 2004. ISBN 8429143130.
- Wark, Kenneth [et al.]. Termodinámica [on line]. 6a ed. Madrid: McGraw-Hill, 2001 [Consultation: 03/10/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=4153. ISBN 9788448191214.

Complementary:

- Professors del Departament de Màquines i Motors Tèrmics. Termodinàmica : taules i gràfiques de propietats termodinàmiques. 2a ed. Barcelona: ETSEIB. CPDA, 2015.
- Montserrat, S. [et al.]. Pràctiques de laboratori de termodinàmica. 6a ed. Terrassa: U.D.I. Termodinàmica i Físico-química E.T.S.E.I.A.T., 2010.

RESOURCES

Audiovisual material:

- Apunts realitzats pel professorat de l'assignatura