UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
240752 - 240752 - Thermodynamics

Last modified: 16/05/2023

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGIES AND ECONOMIC ANALYSIS (Syllabus 2018). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: Fernandez Francos, Xavier

Others: Fernandez Francos, Xavier
Konuray, Ali Osman

REQUIREMENTS

Thermodynamics background provided in Physics I and essential calculus skills.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEGTI 7. (ENG) Coneixements de fluïds, termodinàmica aplicada, transmisió de calor i engineria térmica.

Generical:
CGGTI 3. (ENG) Coneixement en matèries bàsiques i tecnològiques que capacitin per a l'aprenentatge de nous mètodes i teories, i doti de versatilitat per adaptar-se a noves situacions.
CGGTI 4. (ENG) Capacitat pe resoldre problemes amb iniciativa, presa de decisions, creativitat, raonament crític i de comunicar i transmetre coneixements, habilitats i destreses en el camp de l'Enginyeria Industrial.
CGGTI 5. (ENG) Coneixements per a la realització de medicions, càlculs, valoracions, tasacions, peritacions, estudis, informes, plans de treball i altres treballs similars.
CGGTI10. (ENG) Capacitat de treballar en un entorn multilingüe i multidisciplinar.

Transversal:
CT4. (ENG) TREBALL EN EQUIP: Ser capaç de treballar com a membre d'un equip interdisciplinar, ja sigui com un membre més, o realitzant tasques de direcció, amb la finalitat de contribuir a desenvolupar projectes amb pragmatisme i sentit de la responsabilitat, assumint compromisos tenint en compte els recursos disponibles.
CT5. (ENG) ÚS SOLVENT DELS RECURSOS D'INFORMACIÓ: Gestionar l'adquisició, l'estructuració, l'anàlisi i la visualització de dades i informacions en l'àmbit d'especialitat i valorar de forma crítica els resultats d'aquesta gestió.
CT6. (ENG) APRENENTATGE AUTÒNOM: Detectar mancances en el propi coneixement i superar-les mitjançant la reflexió crítica i l'elecció de la millor actuació per ampliar aquest coneixement.
CT7. (ENG) TERCERA LLENGUA: Conèixer una tercera llengua, preferentment l'anglès, amb un nivell adequat oral i escrit, i en consonància amb les necessitats que indran els titultats i titulades.

Basic:
CBGTI2. (ENG) Que els estudiants sàpiguen aplicar els seus coneixements al seu treball o vocació d'una forma professional i tinguin les comptències que se solen demostrar mitjançant l'elaboració i defensa d'argumnets i la resolució de problemes dins de la sera àrea d'estudi.
CBGTI5. (ENG) Que els estudiants hagin desenvolupat aquelles habilitats d'aprenentatge necessàries pe emprendre estudis posteriors amb un alt grau d'autonomia.
CBGTI4. (ENG) Que els estudiants puguin transmetre informació, idees, problemes i solucions a un públic tant especialitzat, com no especialitzat.

TEACHING METHODOLOGY

The main theoretical concepts will be introduced and discussed during lectures in classroom. Numerical examples and problems will be analysed and solved in the classroom in order to understand the application of such concepts. The students will learn the basics tools for analysis of energetic processes and to make use of thermodynamics data available as tables, diagrams and property plots. They will also be encouraged to gain better understanding through the use of software tools (Engineering Equation Solver EES, CoolProp) for quick analysis and solution of problems and the analysis of more complex situations.
The students will be required to solve individually a number of problems/tests in the classroom or at home (the Atenea platform may be used for that purpose) as part of a continuous evaluation system. The students will also participate in five experimental laboratory sessions (small groups) of two hours each.

LEARNING OBJECTIVES OF THE SUBJECT

The main goal of this subject is to apply the Thermodynamics laws to processes of industrial interest, especially those involving energy transformation. Special attention will be paid to thermodynamic cycles for the production of power, cold and heat, and thermodynamics of combustion and humid air.
After completing the subject, the student should be able to:
- Define correctly and solve mass, energy, entropy and exergy balances for simple processes and complex systems involving transformation of energy such as Thermodynamic cycles.
- Handle different sources of thermodynamic data such as tables and plots or other tools in order to determine relevant properties required to solve problems or analyse systems.
- Analyse and interpret the results obtained in the solution of a problem taking into consideration its definition and consistency with basic Thermodynamics laws.
- Analyse the applicability of Thermodynamics models, phenomena related to the content of the subject and assess the performance of real systems on the basis of experimental data.

STUDY LOAD

Type	Hours	Percentage
Hours large group	50,0	33.33
Hours small group	10,0	6.67
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

1. Properties of pure substances

Description:
PvT surface of a pure substance. Pv, Tv and PT diagrams. Tables and property plots. Analytical expressions for PvT relationships. Principle of corresponding states and departure functions.

Specific objectives:
Acquisition of a methodology for the determination and estimation of thermodynamic properties of pure substances.
Application of the energy balance for closed systems and related problem solving.

Related activities:
Activity 1. Laboratory practicum session 1. PvT properties of pure substances.
Activity 7. Problem solving outside the classroom

Full-or-part-time: 34h
Theory classes: 5h
Practical classes: 6h
Laboratory classes: 2h
Self study : 21h

2. Energy balance in open systems

Description:
Mass and energy balances in open systems. Continuity equation. Analysis in control volumes for steady state and transient systems. Application of energy balance to systems found in engineering applications: filling and emptying of vessels, boilers, throttling valves, heat exchangers, nozzles, diffusers, compressors and turbines.

Specific objectives:
Application of mass and energy balances in open systems for problem solving.

Related activities:
Activity 8. Laboratory practicum 1. Gas compression under low pressure.
Activity 6. Individual continuous evaluation test in the classroom.
Activity 7. Problem solving outside the classroom

Full-or-part-time: 21h 30m
Theory classes: 3h 30m
Practical classes: 3h
Laboratory classes: 2h
Self study : 13h

3. Entropy and exergy balances in open systems

Description:
Entropý balance in open systems. Analysis of control volumes. Isentropic efficiency. T-s and h-s diagrams. Exergy. Lost work. Exergy balance in open systems. Exergy efficiency.

Specific objectives:
Use of entropy data for the calculation of isentropic efficiency.
Application of the entropy and exergy balances in their different forms for problem solving.

Related activities:
Activity 7. Problem solving outside the classroom

Full-or-part-time: 15h
Theory classes: 3h
Practical classes: 3h
Self study : 9h

4. Vapor expainsion power cycles

Description:
Analysis of thermodynamic cycles. Basic Rankine cycle. Rankine cycle enhancements: superheating, reheating, regeneration. Cogeneration. Exergy analysis of power plants.

Specific objectives:
Sketch Rankine power cycle diagrams and represent cycles in T-s diagrams.
Energy and exergy analysis of Rankine power cycles.

Related activities:
Activity 6. Individual continuous evaluation test in the classroom.
Activity 7. Problem solving outside the classroom

Full-or-part-time: 18h 30m
Theory classes: 3h 30m
Practical classes: 4h
Self study : 11h

5. Gas power cycles

Description:
Reciprocating internal combustion engines. Indicator diagram. Air-standard and cold-air-standard assumptions. Otto cycle. Diesel cycle. Ericsson and Stirling cycles. Open and closed gas turbines. Brayton cycle. Regenerative Brayton cycle. Gas turbine with intermediate reheating and cooling. Gas and vapor combined cycles.

Specific objectives:
Analysis of Otto, Diesel and Dual cycles.
Energy and exergy analysis of gas turbine cycles.

Related activities:
Activity 3. Laboratory practicum session 3. Stirling engine
Activity 6. Individual continuous assessment tests in the classroom
Activity 7. Problem solving outside the classroom

Full-or-part-time: 19h
Theory classes: 3h 30m
Practical classes: 2h 30m
Laboratory classes: 2h
Self study : 11h

6. Refrigeration cycles and heat pumps

Description:
Vapor compression refrigeration cycles. Heat pump. Coefficient of performance. Properties of regrigerants. Multi-stage and cascade refrigeration cycles. Gas refrigeration cycles.

Specific objectives:
Analysis of vapor compression refrigeration cycles and gas refrigeration cycles.

Related activities:
Activity 4. Laboratory practicum 4. Vapor compression refrigeration cycle using R-134a.
Activity 7. Problem solving outside the classroom

Full-or-part-time: 15h
Theory classes: 2h
Practical classes: 2h
Laboratory classes: 2h
Self study : 9h

7. Non-reactive ideal gas mixtures: humid air

Description:
Ideal gas mixtures. Basic psychrometry concepts. Humid air. Mass and energy balances in humid air systems. Adiabatic saturation temperature and wet bulb temperature. Psychrometric diagram. Air conditioning processes.

Specific objectives:
Application of mass and energy conservation principles to the analysis of air conditioning processes.
Use of psychrometric diagram for the analysis of air conditioning processes.

Related activities:
Activity 5. Laboratory practicum 5. Air conditioning processes.
Activity 6. Individual continuous assessment tests in the classroom
Activity 7. Problem solving outside the classroom

Full-or-part-time: 15h 30m
Theory classes: 2h 30m
Practical classes: 2h
Laboratory classes: 2h
Self study : 9h

8. Reactive mixtures: combustion

Description:
Thermodynamics of reactive systems. Combustion. Stoichiometric air and excess air. Mass and energy balances in reactive mixtures. Absolute entropy. Standard enthalpies of combustion and formation. Higher and lower heating values. Adiabatic flame temperaure. Entropy balance in reactive systems. Exergy analysis.

Specific objectives:
Application of mass and energy balances to reactive mixtures.

Related activities:
Activity 7. Problem solving outside the classroom

Full-or-part-time: 11h 30m
Theory classes: 2h 30m
Practical classes: 2h
Self study : 7h

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GRADING SYSTEM

The students will be graded on the basis of four marks
1) The final exam mark (Mfe)
2) The partial exam mark (Mpe)
3) Laboratory mark (Mlab)
4) Continuous evaluation mark (Mce)

The final mark Mfinal will be calculated following this formula:
Mfinal=0,55*Mfe+0,1*max(Mpe,Mfe)+0,1*Mlab+0,25*max(Mce,Mfe)
Where max() indicates that the highest of the two values will be used.

The final exam will be carried out at the end of the period on the date specified by the School, and will consist in numerical problems. The partial exam will be carried out in the middle of the period on the date specified by the School, and will consist in theoretical and numerical questions. The students will be allowed the use of a handwritten formulae sheet, the book of thermodynamic tables and plots and a calculator.

The laboratory mark will be obtained from the evaluation of the different laboratory sessions, which will include a preliminary report, the laboratory session report, and an individual assessment of the work in the laboratory.

With regards to the 25 % of the mark corresponding to continuous evaluation, 10% will be obtained from evaluation tests in the classroom (previously announced) and the remaining 15 % will be obtained from a set of online tests and problems.

Students failing the subject will be allowed one retake exam. In that case, the final mark will be calculated as:
Minal=0,9*Mre+0,1*Mlab
Where Mre is the mark obtained in the retake exam, which will take place on the date specified by the School. The retake exam will have the same characteristics as the final exam. Mlab is the laboratory mark obtained in the previous period.

Students retaking the subject but who passed the laboratory evaluation may keep their previous laboratory mark (Mlab) and therefore they do not need to do laboratory sessions again. In that case, they should communicate their intention to the coordinator of the subject.

BIBLIOGRAPHY

Basic:
- Moran, M. J.; Shapiro, H. N. Fundamentos de termodinámica técnica [on line]. 2a ed. Barcelona: Reverté, 2004 [Consultation: 07/09/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_Escritorio_Visualizar?cod_primaria=1000193&libro=7704. ISBN 8429143130.
- Çengel, Yunus A [et al.]. Termodinámica [on line]. 9a ed. México, D.F.: McGraw-Hill, 2019 [Consultation: 18/09/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=8722. ISBN 9781456272081.

Complementary:
- Van Wylen, Gordon John; Sonntag, Richard Edwin; Borgnakke, Claus. Fundamentos de termodinámica. 2ª ed. México: Limusa-Wiley, cop. 1999. ISBN 9681851463.
- Wark, Kenneth. Termodinámica [on line]. 6ª ed. Madrid [etc.]: McGraw-Hill, cop. 2001 [Consultation: 18/09/2020]. Available on: http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=4153. ISBN 844812829X.

RESOURCES

Other resources:
Book of tables and diagrams of thermodynamics properties
Thermodynamics. Test and problems.
Extra material can be found in the Atenea platform, such as laboratory practicum procedures, problems, questions and quiz-type tests. The students will also find specific material from each teacher.