INSTITUTO POLITÉCNICO DE BRAGANÇA

Course Unit	Physical Chemistry and Thermochemistry			Field of study	Physics/Chemistry		
Bachelor in	Renewable Energy Engineering			School	School of Technology and Management		
Academic Year	2022/2023	Year of study	2	Level	1-2	ECTS credits	6.0
Type	Semestral	Semester	1	Code	9910-743-2104-00-22		

Workload (hours)	162	Contact hours	T	TP	PL	TC	S	E	OT	O
			30	-	30	-	-	-	-	-

T - Lectures; TP - Lectures and problem-solving; PL - Problem-solving, project or laboratory; TC - Fieldwork; S - Seminar; E - Placement; OT - Tutorial; O - Other

Name(s) of lecturer(s): Paulo Miguel Pereira de Brito

Learning outcomes and competences

At the end of the course unit the learner is expected to be able to:
1. Recognize the importance of thermodynamics in the design, development and operation of processes, pursuing an efficient use of energy.
2. Apply and explain the laws of thermodynamics. Distinguish between thermal effects: phase change, formation, reaction, mixture and dissolution enthalpies. Develop mass, energy and entropy balances.
3. To have the knowledge of different renewable energy forms; advantages and disadvantages. Define energetic equivalent and the main environmental factors in the production of energy.
4. Use and know experimental methods to measure thermodynamic properties.
5. Select the most appopriate alternatives for energy production.
6. Understand processes like hydrolysis, fermentation, combustion, etc., as well as the importance of separation processes in the efficient production of energy.

Prerequisites

Before the course unit the learner is expected to be able to:
1. Apply mathematics, particularly differential and integral calculus.
2. Use of informatic tools such as MATLAB or MS Excel.

Course contents

Fundamental concepts and definitions. First law of thermodynamics. Thermodynamic properties and phase equilibria of pure fluids and mixtures. Thermal effects in chemical processes. Second and third law of thermodynamics. Mass, energy and entropy balances. Energy integration. Energy from different sources.

Course contents (extended version)

1. Introduction
   - The importance of thermodynamics.
   - Dimensions and unites.
   - Fundamental concepts: system, surroundings, temperature scale, force, pressure and volume.
   - Different forms of energy: heat and work.
2. First law of Thermodynamics and other Fundamental Concepts
   - Joule experiments. Definition of internal energy.
   - Mathematical expression for the first law.
   - State functions and entalphy. First law applied to steady state flow processes.
   - Equilibrium state of a system and Gibbs phase rule.
   - Reversible processes. Constant volume or constant pressure processes. Heat capacities.
3. Thermodynamic Properties and Phase Equilibria
   - Phase changes of pure substances. Clausius-Clapeyron equation.
   - Phase rule and Duhem theorem.
   - Raoult and Henry laws.
   - Phase diagrams. Colligative properties.
4. Thermal Effects
   - Heat capacities and its change with temperature.
   - Phase change enthalpies
   - Standard enthalpies of formation, reaction and combustion.
   - Dissolution and mixing enthalpies
5. Second Law of Thermodynamics
   - Second law of thermodynamics. Heat machines. Carnot Cycle.
   - Entropy concept. Entropy changes in processes.
   - Mathematical expression for the second law of thermodynamics. Entropy as equilibrium criterium.
   - Third law of thermodynamics.
   - Thermodynamic analysis of processes: ideal and lost work, and efficiency.
6. Flow processes thermodynamics
   - Control volume and surface. Balance equations: masses, energy, and entropy.
   - Thermodynamic analysis of processes. Calculation of ideal work and thermodynamic efficiency.
   - Relation between lost work and entropy generation. Internal and external irreversibility.
   - Flow of compressible fluids. Expansion and compression processes.
7. Heat and Power Integration
   - Introduction. Capital and energy costs. Approximate capital costs by heat exchangers sizing.
   - Minimum utility targets: temperature-interval, composite curve and linear programming methods.
   - Importance in the selection of the minimum approach temperature in the heat exchangers (DTmin).
   - The pinch point, minimum cool and heat utilities.
   - Maximum energy recovery (MER) networks. Rules for stream matching at the pinch.
   - Minimum number of heat exchangers. Breaking heat loops to reduce the number of heat exchangers.
   - Identifying heat paths and perform energy relaxation.
   - Stream splitting: combining the minimum number of heat exchangers and MER. Stream splitting rules.
   - Threshold temperature, selection of DTmin and multiple utilities.
8. Energy from Different Sources

Recommended reading

1. J. M. Smith; H. C. Van Ness e M. M. Abbott, Introduction to Chemical Engineering Thermodynamics, 7th Edition, McGraw-Hill, 2005.
2. J. W. Tester; E. M. Drake; M. J. Driscoll; M. W. Golay e W. A. Peters, Sustainable Energy: Choosing Among Options, 1st Edition, MIT. Press, 2005.
3. A. V. Rosa, Fundamentals of Renewable Energy Processes, 1st Edition, Elsevier Academic Press, 2005.
4. G. Boyle; B. Everett; J. Ramage, Energy Systems and Sustainability, 1st Edition, Oxford University Press, 2003.
5. S. I. Sandler, Chemical, Biochemical, and Engineering Thermodynamics, 4th edition, John Wiley & Sons, 2006.

Teaching and learning methods

Theoretical analysis of fundamental tools and concepts for the compreension, application and calculations in the thermodynamics area. Presentation of practical examples and model exercices. Problem solving and critical analysis of the results. Evaluation of homework. Development of application projects.

Assessment methods

1. Alternative 1 - (Regular, Student Worker) (Final)
   - Case Studies - 10% (Solution and critical analysis of selected problems)
   - Intermediate Written Test - 80% (2 partial tests (40+40%))
   - Practical Work - 10%
2. Alternative 2 - (Regular, Student Worker) (Final, Supplementary, Special)
   - Final Written Exam - 100% (Global exam)

Language of instruction

Portuguese, with additional English support for foreign students.

Electronic validation

Paulo Miguel Pereira de Brito	Hélder Teixeira Gomes	Ana Maria Alves Queiroz da Silva	Paulo Alexandre Vara Alves
10-10-2022	22-10-2022	24-10-2022	24-10-2022