Course syllabus

Termodynamik för energiingenjörer
Thermodynamics for Energy Engineers

MVKF30, 7,5 credits, G2 (First Cycle)

Valid for: 2023/24
Faculty: Faculty of Engineering, LTH
Decided by: PLED M
Date of Decision: 2023-04-11

General Information

Elective for: MD4, W4-et
Language of instruction: The course will be given in Swedish

Aim

The aim of the course is to provide basic knowledge and skills in technical thermodynamics, with main applications in the energy sector. The course is based entirely on classical thermodynamics, which deals with the subject from a macroscopic perspective. Classical thermodynamics is a natural complement to the statistical thermodynamics given in other thermodynamics courses.

Thermodynamics is based on 4 main laws, all of which constitute generalizing formulations of experimental experiences. The course aims to develop these main laws to also include open systems. Examples of open systems are heat exchangers, turbines, compressors and valves. The purpose of the course is fulfilled by:

- deepen the understanding of the first and second laws of thermodynamics applied to both closed as well as open systems.
- expand the second law to include analysis with entropy balance for closed as well as open systems.
- show how thermodynamics can be used to measure the quality of different energy currents.
- calculate the energy quality of energy currents and systems using exergy analysis for both closed and open systems.
- expand the thermodynamic knowledge of technological power processes such as the

steam power cycle, gas turbine cycle, Diesel and Otto cycle. The goal is for the students to be able to analyze the entire cycle's performance but also be able to analyze the parts of these cycles.
- compressor-driven evaporative cooling process, heat pumps, the concepts of subcooling and overheating.
- perform calculations for open systems containing moist air such as air conditioning.

Learning outcomes

Knowledge and understanding
For a passing grade the student must

- briefly and generally formulate basic state, mass, energy, entropy, and exergy relationships for open and closed systems, with some understanding of their limitations and applicability.
- explain basic thermodynamic concepts that are relevant to technical energy processes.
- account for and, based on basic relationships and principles, derive certain technically important relationships for the subject

Competences and skills
For a passing grade the student must

- in a systematic way solve basic energy problems, with a good engineering management of state tables and diagrams.
- briefly describe, clarify and analyse certain technically important thermodynamic processes, including quantitative assessment of the impact on the environment (entropy generation).
- analyse, formulate, model and solve problems for technical systems and devices with different types of energy exchange and energy conversion for closed and open systems within the subject area of the course.
- apply the system approach as a method for identifying subsystems and components of technical systems.
- analyze systems and determine the state of the system and through tables produce state quantities.

Judgement and approach
For a passing grade the student must

- communicate in writing in a well structured, understanding-oriented and illustrative way regarding problem solving with regard to limitations, reasonableness, accuracy and source statements.
- evaluate technical solutions from an exergy perspective.
- assess the (engineering) plausibility of a solution.

Contents

In thermodynamics (equivalent to 5 credits), classical thermodynamics is treated from a system perspective. A project work (equivalent to 2.5 credits) within one of the subject of the course. The following parts of the technical (classical) thermodynamics covered by the course are:

1. INTRODUCTION AND BASIC CONCEPTS, Thermodynamics and Energy, Importance of Dimensions and Units, Systems and, Control Volumes, Properties of a System, Density and Specific Gravity, State and Equilibrium, Processes and Cycles, Temperature and, the Zeroth Law of Thermodynamics, Pressure, Pressure Measurement Devices, Problem-Solving Technique

2. ENERGY, ENERGY TRANSFER, AND GENERAL ENERGY ANALYSIS, Introduction, Forms of Energy, Energy Transfer by Heat, Energy Transfer by Work, Mechanical Forms of Work, The First Law of Thermodynamics, Energy Conversion Efficiencies, Energy and, Environment

3. PROPERTIES OF PURE SUBSTANCES, Pure Substance, Phases of a Pure Substance, Phase-Change Processes of Pure, Substances, Property Diagrams for Phase-Change Processes, Property Tables, The Ideal-Gas Equation of State, Compressibility, Factor—A Measure of Deviation from Ideal-Gas Behavior, Other Equations of State

4. ENERGY ANALYSIS OF CLOSED SYSTEMS, Moving Boundary Work, Energy Balance for Closed Systems, Specific Heats, Internal Energy, Enthalpy, and Specific Heats of Ideal Gases, Internal Energy, Enthalpy, and Specific Heats of Solids and Liquids,

5. MASS AND ENERGY ANALYSIS OF CONTROL VOLUMES, Conservation of Mass, Flow Work and the Energy of a Flowing Fluid, Energy Analysis of Steady-Flow Systems, Some Steady-Flow Engineering Devices, Energy Analysis of Unsteady-Flow Processes,

6. THE SECOND LAW OF THERMODYNAMICS, Introduction to the Second Law, Thermal Energy Reservoirs, Heat Engines, Refrigerators and Heat Pumps, Perpetual-Motion Machines, Reversible and Irreversible Processes, The Carnot Cycle, The Carnot, Principles, The Thermodynamic Temperature Scale, The Carnot Heat Engine, The Carnot Refrigerator and Heat Pump

7. ENTROPY, Entropy, The Increase of Entropy Principle, Entropy Change of Pure Substances, Isentropic Processes, Property Diagrams Involving Entropy, What is Entropy, The T ds Relations, Entropy Change of Liquids and Solids, The Entropy Change, of Ideal Gases, Reversible Steady-Flow Work, Minimizing the Compressor Work, Isentropic Efficiencies of Steady-Flow Devices, Entropy Balance

8. EXERGY, Exergy: Work Potential of Energy, Reversible Work and Irreversibility, Second-Law Efficiency, Exergy, Change of a System, Exergy Transfer by Heat, Work, and Mass, The Decrease of Exergy Principle and Exergy Destruction, Exergy, Balance: Closed Systems, Exergy Balance: Control Volumes

9. GAS POWER CYCLES, Basic Considerations in the Analysis of Power Cycles, The Carnot Cycle and its Value, in Engineering, Air-Standard Assumptions, An Overview of Reciprocating Engines, Otto Cycle: the Ideal Cycle for Spark-Ignition, Engines, Diesel Cycle: the Ideal Cycle for Compression-Ignition Engines, Stirling and Ericsson Cycles, Brayton Cycle: the Ideal, Cycle for Gas-Turbine Engines, The Brayton Cycle with

Regeneration, The Brayton Cycle with Intercooling, Reheating, and Regeneration, Ideal Jet-Propulsion Cycles, Second-Law Analysis of Gas Power Cycles

10. VAPOR AND COMBINED POWER CYCLES, The Carnot Vapor Cycle, Rankine Cycle: the Ideal Cycle for Vapor Power Cycles, Deviation of Actual Vapor Power Cycles From Idealized Ones, How Can we Increase the Efficiency of the Rankine Cycle, The Ideal, Reheat Rankine Cycle, The Ideal Regenerative Rankine Cycle, Second-Law Analysis of Vapor Power Cycles, Cogeneration, Combined Gas–Vapor Power Cycles

11. REFRIGERATION CYCLES, Refrigerators and Heat Pumps, The Reversed Carnot Cycle, The Ideal Vapor-Compression, Refrigeration Cycle, Actual Vapor-Compression Refrigeration Cycle, Second-Law Analysis of Vapor-Compression Refrigeration Cycle, Selecting the Right Refrigerant, Heat Pump Systems, Innovative Vapor-Compression Refrigeration Systems, Gas Refrigeration Cycles, Absorption Refrigeration Systems

12. THERMODYNAMIC PROPERTY RELATIONS, A Little Math—Partial Derivatives, The Maxwell Relations, The Clapeyron, Equation, General Relations for du, dh, ds, cv, and cp, The Joule-Thomson Coefficient, The dh, du, and ds of Real Gases,

13. GAS MIXTURES, Composition of a Gas Mixture: Mass and Mole Fractions, P-v-T Behavior of Gas Mixtures: Ideal, and Real Gases, Properties of Gas Mixtures: Ideal and Real Gases

14. GAS–VAPOR MIXTURES AND AIR-CONDITIONING, Dry and Atmospheric Air, Specific and Relative Humidity of air, Dew-Point Temperature, Adiabatic Saturation and Wet-Bulb Temperatures, The Psychrometric Chart, Human Comfort and Air-Conditioning, Air-Conditioning Processes

Examination details

Grading scale: TH - (U,3,4,5) - (Fail, Three, Four, Five)
Assessment: One written test, mainly theory; individual problem assignments; and a final written examination on problem-solving. The course mark is determined from a weighted total sum, which consists of the result from the passed written examination including bonus points from approved problem assignments (if given) and the passed test. The graduation is determined from a special formula.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Parts
Code: 0323. **Name:** Project Assignment.
Credits: 2,5. **Grading scale:** TH. **Assessment:** Project report.
Code: 0423. **Name:** Exam.
Credits: 5. **Grading scale:** TH. **Assessment:** Written exam

Admission

Assumed prior knowledge: FMAA01 Calculus in One Variable. FMA420/FMAB20 Linear Algebra, FMA430/FMAB30 Calculus in Several Variables
The number of participants is limited to: No
The course overlaps following course/s: MMVF01

Reading list

- Çengel, Y. A., Boles, M. A., Kanoglu, M.: Thermodynamics – An Engineering Approach, Ninth Edition in SI Units. McGraw-Hill, 2020, ISBN: 978-981-3157-87-3. Previous editions in SI units work well (5th to 8th).
- Supplementary material can be purchased from university book shop (KFS).

Contact and other information

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