MASTER OF SCIENCE
IN ENGINEERING

Module Description

Advanced Thermodynamics

General Information

Number of ECTS Credits

3

Abbreviation

TSM_AdvTherm

Version

26.07.2016

Responsible of module

Prof. Dr. Timothy Griffin

Language

	Lausanne	Bern	Zurich
Instruction	☐ E ☒ F	☐ D ☐ E ☐ F	☐ D ☒ E
Documentation	☒ E ☒ F	☐ D ☐ E ☐ F	☐ D ☒ E
Examination	☒ E ☒ F	☐ D ☐ E ☐ F	☒ D ☒ E

Module category

☐ Fundamental theoretical principles - FTP
☒ Technical/scientific specialization module - TSM
☐ Context module - CM

Lessons

☒ 2 lecture periods and 1 tutorial period per week
☐ 2 lecture periods per week

Brief course description of module objectives and content

In Part A this module reviews the subjects of basic engineering thermodynamics (energy, entropy and material balances, fluid properties, and important thermodynamic cycles) and extends knowledge to deal with real fluids, phase and chemical equilibria, system stability, and processes with chemical transformation.

Additionally, in Part B the students will learn to draw connections between detailed, thermodynamic formulae and full thermodynamic systems. The basic tools of thermodynamics (balances of conservative quantities) will be employed to model any complex, thermodynamic system. Selected examples will illustrate the utility of applying thermodynamics in various practical fields.

Aims, content, methods

Learning objectives and acquired competencies

Part A:

The achievement of the main goals in Part A is associated with the following competencies:

- Ability to set up and solve energy and entropy balances for open and closed thermodynamic systems.
- Ability to determine the properties of non-ideal gases and gas mixtures using corresponding states and/or a cubic equation of state.
- Understanding the Gibbs free energy and chemical potential and to be able to calculate conditions for thermal, phase and chemical equilibrium.

Part B:

- Intensify the understanding of some areas from Part A, by applying the gained knowledge in terms of model building of dynamic systems (e.g.: chemically reacting systems, irreversible levelling processes)
- Get an idea of the complexity of modern thermodynamic equilibrium solvers (Method of Lagrangian Multipliers)
- Understand examples of how Advanced Thermodynamics is applied in practice (modeling of complex thermo-chemical processes, e.g. wood gasification, Richardson Ellingham diagram, analysis of cycle processes)
- Apply mass and energy balances within systems with chemical reactions, e.g. to calculate adiabatic reaction/flame temperatures.

Contents of module with emphasis on teaching content

Part A:

Part A starts with a review of basic principles, conservation equations for mass, energy and entropy and their application. Important thermodynamic cycles are analyzed and the Gibbs Free Energy is introduced. The interrelations between thermodynamic variables are introduced and used as the basis for calculating deviations from ideal gas behavior using a cubic equation of state. The necessity for partial molar properties to describe real mixtures is shown and the chemical potential is introduced. Conditions for phase and chemical equilibrium are derived and employed in simple systems.

Weekly problem sets dealing with the topics are distributed and solutions discussed with the class.

Part B:

Part B starts with the repetition and consolidation of selected fields from part A by transferring the knowledge to application via modelling thermodynamic systems. Introducing and using a System Dynamic methodology (supported by the software Berkeley Madonna, to model interacting systems (e.g.: chemically reacting species, irreversible levelling), two goals are achieved:

- Students get a visualized impression of dependencies
- Students can connect detailed formulae with a large scale system overview.

As part B progresses, application examples from practice are presented:

- The structure of modern thermodynamic equilibrium solvers in the context of modelling complex thermo-chemical processes (e.g. wood gasification)
- The Richardson Ellingham, its connection to the learned content and its wide spread application within metallurgy
- Analysis of basic and more advanced cycle processes (e.g.: Diesel cycle, Stirling cycle)

The thermodynamic basics of chemical reactor engineering (heat-, mass balancing in tank- and tube reactors, reaction- and flame temperatures) are discussed as well.

Teaching and learning methods

Lectures with discussion, Interactive derivations on blackboard, supported by PPT slides, weekly problem sets with solutions. In Part A some exercises will be solved using Matlab and/or Mathcad software. (Mathcad Software will be provided.) In Part B exercises require the System Dynamic software Berkeley Madonna. Trial versions (sufficient for the course) available online for free.

Prerequisites, previous knowledge, entrance competencies

Successful completion of a bachelor degree course on basic engineering thermodynamics

Literature

Sandler, S.I..(1940). Chemical and Engineering Thermodynamics, 1989, ISBN 978-0-471-66174-0

Dunn I.J., et., al. (2003). Appendix: Using the Berkeley Madonna Language, in Biological Reaction Engineering: Dynamic Modelling Fundamentals with Simulation Examples. 2003, Doi: 10.1002/3527603050.app1

Boiger, G., (2014). System Dynamic modeling approach for resolving the thermo-chemistry of wood gasification. Int. J. Mult. Ph. 2015.

Assessment

Certification requirements for final examinations (conditions for attestation)

none

Written module examination

Duration of exam:	120 minutes
Permissible aids:	Notes and printed course presentations, course textbooks