UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Non Equilibrium Thermodynamics

2627-1-F5402Q015

Aims

The aim of the course is to provide students with a modern conceptual framework of the thermodynamics of systems out of equilibrium. Examples of notable applications wil be given.

Knowledge and understanding

- Use of proper theoretical models in the analysis of out-of-equilibrium systems
- Procedures to compute non-equilibrium thermodynamic quantities
- Criteria for the evaluation of stability in out-of-equilibrium thermodynamic systems

Applying knowledge and understanding

- Writing evolutionary equations of non-equilibrium thermodynamic systems
- Analysis of the connections between thermodynamics and statistical mechanics out of equilibrium
- Tools to analyze energy conversion systems also in view of their sustainability

Making judgments

- Development of critical capacities in the use of non-equilibrium thermodynamic potentials
- Ability to critically analyze thermodynamic theories

Communication skills

Rigorous use of natural language in science

Learning skills

Activation of critical skills in the analysis of scientific models

Contents

Equilibrium thermodynamics from a superior point of view. Near.equilibrium thermodynamics. Heat engines out of equilibrium. Far-from-equilibrium thermodynamics. Dynamic systems.

Detailed program

Equilibrium Thermodynamics from a Superior Point of View
Scope and Definitions; The Fundamental Laws; Gibbs' Equation; Fundamental Relations and State Equations; Euler's Relation; Gibbs–Duhem's Relation; Legendre Transformations and Thermodynamic Potentials; Extremum Principles; Stability of Equilibrium States; Equilibrium Chemical Thermodynamics.

Near-Equilibrium Thermodynamics
Basic Concepts; Local Equilibrium Hypothesis; Entropy Balance; Evolution Equations; Stationary States; Applications to Heat Conduction and Mass Transport; Limitations of the Classical Theory of Irreversible Thermodynamics. Coupled Transport Phenomena: Electrical Conduction; Thermoelectric Effects; Thermodiffusion; Diffusion Through a Membrane.

Heat Engines out of equilibrium
Finite-Time Thermodynamics; The Finite-Time Carnot Cycle and the Curzon–Ahlborn's Model; Exo-reversible and Endo-reversible Heat Engines. Sustainability from the thermodynamic viewpoint.

Far-from-equilibrium Thermodynamics
Scope of Extended Irreversible Thermodynamics; Fourier's vs. Cattaneo's Law of Heat Conduction; Extended Entropy; Application to Steady Heat Transport in Nano-Systems. Einstein's Formula and the Second Moments of Equilibrium Fluctuations; Derivation of the Onsager–Casimir's Reciprocal Relations; Fluctuation-Dissipation Theorem.

Dynamic Systems
Chemical Reactions and Molecular Machines: Single and Coupled Chemical Reactions; Cyclical Chemical Reactions and Onsager's Reciprocal Relations; Efficiency of Energy Transfer; Chemical Reactions, Mass Transport, and Molecular Machines; Autocatalytic Reactions and Diffusion; Morphogenesis. Instabilities and Pattern Formation: Linear and Non-Linear Theories of Stability; Chemical Instabilities; Spatio-Temporal Patterns in Heterogeneous Systems; Turing Structures.

Prerequisites

Basic knowledge of equilibrium thermodynamics and statistical mechanics

Teaching form

24 two-hour lectures, in person, Delivered Didactics
Lectures will be in Italian in the absence of Erasmus students; in English otherwise.

Textbook and teaching resource

Georgy Lebon, David Jou, José Casas Vàzquez, *Understanding Non-equilibrium Thermodynamics: Foundations, Applications, Frontiers*, Springer-Verlag Berlin Heidelberg, 2008, http://login.proxy.unimib.it/login?url=http://dx.doi.org/10.1007/978-3-540-74252-4
Handouts

Semester

First year, second term

Assessment method

Oral exam on topics covered during the class lectures. The oral exam aims at verifying the level of knowledge acquired by the student, his/her understanding of the main conceptual junctures in the development of the theory presented during the class and his/her appropriate use of the natural language.

The grading scale will be as follows:
< 18: Fail; the minimum level of preparation has not been achieved.
18-21: Preparation limited to a small number of topics in the course syllabus, with limited discussion and analysis skills that emerge only with the instructor's assistance and prompting; expression and vocabulary are not always correct, and critical thinking skills are limited.
22-24: Preparation on a portion of the topics in the course syllabus, limited independent analytical skills, use of correct though not fully accurate or clear vocabulary, and occasionally hesitant expression.
25-27: Preparation on a wide range of topics covered in the course syllabus, ability to independently build arguments and critical analysis, ability to apply knowledge to concrete cases, use of correct vocabulary, and competence in the use of subject-specific language.
28-30/30L: Complete and comprehensive preparation on the exam syllabus topics, personal ability for independent discussion and critical analysis of the subjects, excellent critical and independent thinking skills, full mastery of subject-specific vocabulary, and rigorous, articulate expression.

Office hours

By appointment

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY