UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Non Equilibrium Thermodynamics

2223-1-F5401Q068

Aims

The aim of the course is to provide students with a modern conceptual framework of the thermodynamics of systems out of equilibrium, not limited to near-equilibrium thermodynamics. 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; Brownian Motion with Inertia.

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

Classroom lectures.

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

Semester

First year, second semester

Assessment method

Oral exam on topic covered during the lessons. 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 language.

Office hours

By appointment

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY