

## Faculty of Applied Sciences



### MECA2771 Thermodynamics of irreversible phenomena.

[30h+15h exercises] 4 credits

This course is taught in the 2nd semester

**Teacher(s):** François Dupret, Miltiadis Papalexandris  
**Language:** French  
**Level:** Second cycle

#### Aims

- A modern approach to non-equilibrium thermodynamics.
- Unified description of thermal, mechanical, viscous, and electromechanical processes in order to enhance the students' synthetic skills.
- Application of theoretical results in the modelling of irreversible phenomena in fluid and solid mechanics, geophysics, etc.

#### Main themes

- Elaboration of a general theoretical framework of irreversible phenomena having as starting points the kinetic theory of gases and classical thermodynamics
- Presentation of the classical theory of Onsager-Prigogine. Presentation of more recent theories such as Rational Thermodynamics (theory of Truesdell & Noll), Extended Thermodynamics (theories of Jou & Lebon and of Müller), and the theory of Grmella & Ottinger.

#### Content and teaching methods

Kinetic approach :

Presentation of the Maxwell-Boltzmann kinetic theory of gases. Relations between macroscopic variables and kinetic theory. Derivation of principal transport coefficients (viscosity coefficient, conductivity, diffusivity), state equations, thermodynamic functions and their derivatives (internal energy, specific heats, entropy). Limits of continuum theory (rarefied gases, plasma). Study of specific problems in liquids (macromolecules) and solids (plasticity).

Continuum approach :

Summary of classical thermodynamics: first thermodynamic axiom (principle of energy conservation), absolute temperature and entropy, second thermodynamic axiom, thermodynamic potentials, thermochemistry and electrochemistry, Gibbs relations, equation of Gibbs & Duhem, phase transitions, interfaces.

Classical theory of irreversible thermodynamics (linear theory of Onsager-Prigogine) :

Local equilibrium, entropy production, thermodynamic fluxes and forces, reciprocal relations, evolution laws and constitutive relations. Stationary states: criteria for minimum of entropy production and minimum of dissipated energy. Couplings between thermal, mechanical, and electromagnetic phenomena: thermoelectric and thermomagnetic effects.

Introduction in modern theories :

Rational thermodynamics: material memory, objectivity, Clausius-Duhem inequality, constitutive relations. Applications in Non-Newtonian fluids and viscoelastic materials. Extended irreversible thermodynamics: basic hypotheses, causality, application in thermal conduction, second sound, comparison with the linear theory of Onsager-Prigogine. Hamiltonian formulations, Poisson brackets and dissipative brackets.

**Other information (prerequisite, evaluation (assessment methods), course materials recommended readings, ...)**

Prerequisites :

Continuum Mechanics (MECA2901), Thermodynamics (MECA2855), Fluid Mechanics I and II (MECA2321 and MECA2322).

**Other credits in programs**

<b>ELME22/E</b>	Deuxième année du programme conduisant au grade d'ingénieur civil électro-mécanicien (énergie)	(4 credits)	
<b>PHYS22/T</b>	Deuxième licence en sciences physiques (Physique de la terre, de l'espace et du climat)	(4 credits)	Mandatory