MSE-483 ADVANCED PHASE TRANSFORMATIONS

FALL 2025

TEACHER: Prof. Anirudh Raju Natarajan
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LECTURES: 09:15 - 11:00 (MXF1)
EXERCISES: 13:15 - 14:00 (MXF1)

ASSISTANTS: Damien Lee (damien.lee@epfl.ch)

COURSE DESCRIPTION

This course provides an overview of the phenomenological concepts and mathematical tools that have been developed to study the thermodynamics, kinetics and mechanics of phase transformations. We will focus on phase transformations in metallic alloys, energy storage materials, ceramics, electronic materials etc.

COURSE CONTENT

- Review of the mathematical structure of thermodynamics.
- Thermodynamics of first-order and second-order phase transitions.
- Order parameters for phase transformations.
- Thermodynamic descriptions of inhomogeneous systems.
- Kinetics of phase transformations
- Martensitic phase transitions

LEARNING OUTCOMES

Analyze the thermodynamics, kinetics and mechanics of phase transformations

ASSESSMENT METHOD

Oral examination. Date and location will be announced soon.

TEXTBOOK AND COURSE MATERIAL

Course Material

- Course notes will be posted on moodle after class
- Problem sets also posted on the moodle site

Suggested Texts

- Principles of Classical Thermodynamics: Applied to Materials Science Didier de Fontaine
- Theory of Structural Transformations in Solids, Khachaturyan, Dover
- Kinetics of Materials, Balluffi, Allen, Carter, Wiley 2005
- Phase Transformations in Metals and Alloys, Porter and Easterling

TENTATIVE SCHEDULE

Week	Topics
September 11	Introduction, Course overview Thermodynamics of phase transitions *Lecture instead of exercise session*
September 18	Mathematical structure of thermodynamics *Lecture instead of exercise session*
September 25	Equilibrium conditions and phase transitions in unary systems
October 2	Clausius-Clapeyron relation
October 9	Kinetics of phase transitions
October 16	Kinetics of phase transitions
October 23	*Mid-Semester Break*
October 30	Phenomenological theories of spinodal decomposition
November 6	Phenomenological theories of spinodal decomposition
November 13	Descriptors of phase transitions and phase-field models
November 20	Classical Nucleation Theory
November 27	Phase transformations with interfaces
December 4	*No lecture, only exercise session*
December 11	Diffusionless phase transitions
December 18	Diffusionless phase transitions

PEDAGOGIC NOTE

The conceptual complexity of phase transformations will require you to spend some time thinking and analyzing the topics we discuss in class. Lectures will be structured so that we all learn the subject *together*. The collaborative learning experience will be greatly enhanced if you regularly engage with me by asking questions or raising discussion points. It is very likely that *your question* will be on someone else's mind as well! Exercise sessions are aimed at reinforcing concepts discussed during the lecture. It is very important that you attempt to solve the problems by yourself. Inputs you receive from the teaching assistants or your friends on getting started with a problem are often the most difficult steps in the exercises. Some problems have many ways of solving them and I encourage you to explore these alternate solutions.