PHYS-806

Micromagnetics, from Domain Walls to Skyrmions

Thiaville André

Cursus	Sem.	Type
Physics		Obl.

Language of teaching	English
Credits	1
Session	
Exam	Oral
Workload	30h
Hours	**14**
Courses	14
Number of positions	

Frequency

Only this year

Summary

The course will describe the physics of magnetic structures in condensed matter, at the mesoscopic scale i.e. above the atomic scale. This allows understanding the response of magnetic samples to external stimuli.

Content

Micromagnetics is the continuous mechanics that describes the statics and dynamics of magnetic structures (the magnetic domain wall being the ancestor, the magnetic skyrmion the latest addition to that zoo), as soon as their scale is well above the atomic distance and the timescale much larger than the characteristic time of the exchange interaction. With just the numerical values of a few phenomenological parameters, it is possible to quantitatively describe the response of any sample of the corresponding material, given its geometrical shape and the stimuli applied. Over the years, this theory has expanded by including interfacial energy terms, and actions describing the various phenomena of spintronics. Nowadays, several public micromagnetic codes are available to obtain quantitative predictions for more and more complex experimental situations.
The course will propose a step-by-step path through the developments of micromagnetics, working out the key cases. It will be illustrated by experimental images and results. It will be articulated in 4 sessions of 3.5 hours.

1. The magnetism of condensed matter : magnetic moments, exchange, anisotropy, magnetostriction, antisymmetric exchange
2. Magnetostatics of magnetic materials : demagnetizing field, demagnetizing factors, magnetic charges, theorems on magnetostatics
3. Continuous treatment of magnetic structures : history of micromagnetics, conditions for equilibrium, boundary conditions, interfacial energies, the Bloch wall, the magnetic vortex in an ultrthin film, the Néel wall, characteristic lengths of micromagnetics
4. Magnetic domains : monodomain limit, macrospin model, stripe domains in uniaxial materials, domains in soft elements, charged and chargeless domain walls, configuration anisotropy, domains in nanowires
5. Dynamic micromagnetics : the Landau-Lifchitz and landau-Lifchitz-Gilbert equations, energy dissipation, lagrangian formulation, dynamics under spin-transfer torques, numerical micromagnetics
6. Domain wall dynamics : Walker solution, Slonczewski equations, dynamics by spin-transfer torques, 1D vs. 2D dynamics
7. Dynamics of magnetic ttextures : Thiele equation, its modification by spin-transfer torques, brownian motion of localized textures
8. Magnetic substructures : Bloch lines, Bloch point, topological approach, statics and dynamics

Note

Host: F. Mila (EPFL SB IPHYS CTMC)
Swiss Universities

Keywords

Magnetism of matter, magnetic textures, magnetic domain walls, micromagnetics

Learning Prerequisites

Recommended courses

electromagnetism, condensed matter physics
mechanics of continuous media

Expected student activities

to have an intuition of how a given magnetic sample organizes magnetically and responds to external stimuli