The European School on Magnetism 2015 – Magnetization processes and dynamics

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In these lectures magnetization processes are covered within phenomenological continuum theory. The basic ingredients will be introduced in terms of Ginzburg-Landau functionals and dynamical equations. Along our itinerary, some microscopic models for the phenomenological formulations can explain the microscopic underpinning and quantify the various phenomenological parameters arising in these theories.

Basic notion of magnetization dynamics will be introduced for ferromagnetic systems. Within the micromagnetic approximation the Landau-Lifshitz-Gilbert (LLG) equation can be used to describe diverse phenomena from extended oscillatory waves to eigenmodes at and transport of micromagnetic objects as domain walls, vortices, or skyrmions. Extending the dynamics to include longitudinal processes motivates the formulation of the Landau-Lifshitz-Bloch (LLB) equation. Including thermal noise in these deterministic dynamical equations can be achieved in the form of Langevin equations for either formulation. Some pitfalls in the interpretation of these stochastic equations will be highlighted.

In the second half of the lecture, coupled magnetic systems will be introduced where the dynamics and processes of the primary magnetic order (ferromagnetic magnetization but also antiferromagnetic order parameters) are influenced by other degrees of freedom in a material.

Such systems like multiferroics, display a rich phenomenology of processes with a wide perspective to explore new effects. The crucial symmetry considerations in formulating possible couplings between magnetic order parameters and other degrees of freedom provide a secure guideline to construct appropriate phenomenological theories. Some selected examples will be used to illustrate useful approaches towards such complex systems: the dynamics of weak-ferromagnets, i.e. antiferromagnets with canted spin-structure; coupled magnetic and dielectric excitations, called ferroelectromagnons in magnetic dielectrics or ferroelectrics; excitations and waves in magnetoelastically coupled systems. Within such theories, some exotic effects like localized and incommensurate quasi-static states, corresponding non-linear excitations, but also linear non-reciprocal wave propagation can be predicted and analysed.

Some references

Akhiezer, A. I., Bar'yakhtar, V. G., Peletminskii, S. V., & Ilitch, A. (1968). Spin waves.Amsterdam: North-Holland Publishing Company.

Bar'yakhtar, V. G., Chetkin, M. V., Ivanov, B. A., & Gadetskii, S. N. (1994). Dynamics of topological magnetic solitons. Springer Tracts in Modern Physics, 129.

Brown, W. F. (1963) "Micromagnetism." Recent Advances in Engineering Sciences 5.

Garanin, D. A. (1997). Fokker-Planck and Landau-Lifshitz-Bloch equations for classical ferromagnets. Physical Review B, 55(5), 3050.

Hubert, A. & Schäfer, R. (1998).Magnetic domains: the analysis of magnetic microstructures.