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Elementary Transport Theory for Metal Spintronics (3h)

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Much of the "useful" spintronic devices are made from elementary metals and their alloys. Their functionality stems from the robustness of the magnetic order parameter of ferromagnetic metals with respect to elevated temperatures and nanostructuring into thin films and pillars. Typical energy scales in metals such as the Fermi energy and exchange interaction are of the order of 1-10 eV, while Fermi wave and exchange lengths are on an Angstrom scale. In all but atom-sized structures or ultralow temperatures quantum effects due to confinement or disorder can then be safely disregarded, implying that a proper transport theory should be semiclassical and based on Boltzmann theory [1]. However, spintronic devices are often heterostructures made from different metals and insulators that are grown epitaxially. Semiclassical theory fails to describe atomically sharp interfaces that to date are grown routinely.

The topic of this lecture is a pragmatic approach to the theory of transport in metal-based spintronic devices, taking into account abrupt heterointerfaces into an otherwise semiclassical formalism (magnetoelectronic circuit theory), by integrating it with the scattering theory of transport as originally developed by Landauer and Büttiker [2]. Topics to be discussed are:

(1) Elementary transport theory
- (a) Linear response theory of transport
- (b) Scattering theory of transport
- (c) Thermoelectricity and Onsager symmetry
- (d) Semiclassical transport
- (e) Giant magnetoresistance and spin valve effect
- (f) Spin-dependent thermoelectricity

(2) *DC magnetoelectronic circuit theory* [3].
- (a) Transport in non-collinear magnetization textures, non-collinear spin valves
- (b) Spin transfer torque and spin mixing conductance
- (c) Spintronic Kirchhoff Laws

(3) *AC magnetoelectronic circuit theory* [4].
- (a) Current-induced magnetization dynamics
- (b) Spin pumping and enhanced Gilbert damping

(c) Noise in spin valves

Bibliography

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