Exchange and ordering, magnetostriction, localized and band magnetism, interaction with the lattice, magnetic anisotropy and crystalline electric field (3x1.5 hours)

Stephen J. Blundell
University of Oxford

The exchange interaction between magnetic moments arises from the effects of the Coulomb interaction (which corresponds to a large energy) and the exchange symmetry of identical particles. We will consider particular incarnations of the exchange interactions: direct exchange, indirect exchange (superexchange and RKKY), and anisotropic exchange.

The exchange interaction leads to the presence of magnetic order, and we will consider this in both localized and itinerant systems. In the latter case, the magnetization of the electron gas will be treated, including a discussion of Pauli susceptibility and the Stoner criterion. We will also consider the model system of a triangle of spins and solve the problem exactly, revealing the key symmetries.

The Heisenberg model possesses rotational symmetry because the interaction $\boldsymbol{S}_i.\boldsymbol{S}_j$ has no preferred direction. However, magnetic moments in solids are sensitive the presence of the lattice. One consequence of this is magnetocrystalline anisotropy, which has an effect on the thickness of domain walls. Another consequence is magnetostriction.

The presence of the crystalline electric field splits the degeneracy of d-electron states and we will discuss how this leads to orbital quenching and the Jahn-Teller effect. The Goodenough-Kanamori-Anderson rules can be used to understand how superexchange operates in compounds with different geometries.

Further reading:

S. J. Blundell: Magnetism in condensed matter (OUP, 2001).
[my textbook, covers most of the material]

S. J. Blundell, Magnetism: A Very Short Introduction (OUP, 2012).
[popular introduction, for background only]

J.M.D. Coey: Magnetism and magnetic materials (CUP, 2009).
[Mike Coey's textbook, covers a lot of ground]

D.I. Khomskii: Basic aspects of the quantum theory of magnetism (CUP, 2010).
[harder book by a theoretician, but packed full of good insights]