Physics MSc of FNS BME
3. semester

THEORY OF MAGNETISM 2. (3 credits)
lecturer: Attila Virosztek

1. **Spontaneous breaking of symmetry in the Heisenberg model**
   Symmetries of the Heisenberg model and its ground state in the ferromagnetic and antiferromagnetic cases, possibility of global singlet states, the RVB state as spin liquid, the VBS state. (6.3, 6.3.1, 6.3.2)

2. **Crystal field theory, symmetries and degeneracies**
   Magnetism of atoms and ions in solids, crystal field in the perovskite structure, hierarchy of energy scales in case of transition metals and rare earth metals. Symmetry group of the Hamiltonian, energy eigenvalue degeneracies required by the symmetries, representations of the symmetry group, irreducible representations, decomposition of representations using characters, character table. (3.1, 3.2, 3.2.1)

3. **Transition metal atoms in cubic crystal field**
   The octahedral group, symmetries of the atomic states, splitting of a d-level in cubic field, quenching the orbital angular momentum, competition of the exchange and crystal field energies. (3.3, 3.4, 3.5, 3.5.1, 3.5.3)

4. **Further symmetry breakings and symmetries**
   Energy considerations in case of a tetragonal distortion in an octahedral environment, Jahn-Teller effect; time reversal invariance, Kramers' theorem. (3.6, 3.7)

5. **Itinerant ferromagnetism**
   The mean field phase diagram of the one band Hubbard model, exact results (Lieb's theorem, Nagaoka theorem), flat band ferromagnetism; orbital degeneracy, two band (degenerate) Hubbard model, Hund's rule coupling, ground state in the atomic limit, ferromagnetc coupling due to kinetic exchange, orbital ordering. (8.1, 8.2, 8.2.1, 8.2.3, 5.4)

6. **Correlated metals, heavy fermions**
   The metallic ground state on a localized basis, correlated metallic state, Gutzwiller trial state, Gutzwiller approximation, Brinkman-Rice transition, mass enhancement due to correlations, heavy fermions. (9, 10.1, 10.2)

Literature:

Patrik Fazekas: Lecture Notes on Electron Correlation and Magnetism (World Scientific, Singapore, 1999). The numbers at the end of the above topics refer to the relevant chapters of this book.

Prerequisits: Modern solid state physics, Theory of magnetism.
Requirement for signature: Attendance of the lectures.
Grade: Based on oral exam.