General Information			
Course name	Quantum Theory of Magnetism	**ECTS Credits**	5
		Semester	S

Aims

To solve the simplest quantum spin models in the field of quantum theory of magnetism using the advanced methods such as Bethe ansatz, spin-wave theory, Jordan-Wigner fermionization, and variational method.

Content

An introduction to the quantum theory of magnetism, the definition of basic lattice-statistical models in magnetism: Ising model, Heisenberg model, Hubbard model, t-J model. Exchange interaction and its quantum-mechanical origin. Quantum mechanics of the orbital and spin angular momentum. The second-quantization formalism, introduction of raising and lowering (ladder) operators, basic commutation rules between the ladder operators. An elementary quantum theory of two interacting magnetic particles. (1.-3. week)

The ground state and excited states of the one-dimensional quantum Heisenberg model with the ferromagnetic interaction. Spin waves as collective excitations of a spin chain, bound spin excitations. The grounds of Bethe-ansatz method, the examples with two and three spin deviations. The ground state of the one-dimensional quantum Heisenberg model with the antiferromagnetic interaction. A valence-bond crystal as the ground state of two geometrically frustrated Heisenberg models: Majumdar-Ghosh model and Shastry-Sutherland model. (4.-6. week)

The exact solution for the one-dimensional quantum XY model in a transverse magnetic field. The fermionization of spin operators with the help of Jordan-Wigner transformation, Fourier and Bogoliubov transformations. The ground-state energy, magnetization process and quantum critical points. The behaviour of thermodynamic quantities at non-zero temperatures. (7.-9. week)

The spin-wave theory for the generalized quantum Heisenberg model of arbitrary spatial dimension and spin quantum number. The bosonization of spin operators through the Holstein-Primakoff transformation. The simple linear spin-wave theory and the extended theory of interacting spin waves. The simple spin-wave theory for the ferromagnetic and antiferromagnetic quantum Heisenberg model. (10.-13. week)

Assessment Methods and Criteria

Exam

Grading Scale (in %):
A: 91% - 100%
B: 81% - 90%
C: 71% - 80%
D: 61% - 70%
E: 51% - 60%
F: 0% - 50%

Grading System:
The University recognizes the following six degrees for the evaluation of the study results:
a) A – excellent (excellent results) (numerical value 1)

b) B – very good (above average results) (1.5)
c) C – good (average results) (2)
d) D – satisfactory (acceptable results) (2.5)
e) E – sufficient (results meet the minimum criteria) (3)
f) FX –failed (requires further work) (4)

Bibliography

1. J. B. Parkinson, D. J. J. Farnell: An Introduction to Quantum Spin Systems, Lecture Notes in Physics 816, Springer 2010.
2. U. Schollwock, J. Richter, D. J. J. Farnell, R. F. Bishop: Quantum Magnetism,

   Lecture Notes in Physics 645, Springer 2004.

3. N. Majlis, The Quantum Theory of Magnetism, World Scientific 2000.