MAGNETISM AND SUPERCONDUCTIVITY

Lectures on-line by Sabina Lewińska on **Tuesdays, 8:00 - 10:00**

beginning 28 February, 2023; the end: 13 June 2023

The course of 15 lectures is:

- Directed at students of International PhD Studies of the Institute of Physics of the Polish Academy of Sciences
- Aimed at familiarizing participants with fundamentals of magnetism and superconductivity.

After completing the course, the participants:

- Should be able to understand basic ideas of papers on magnetism and superconductivity.
- Should be prepared to study magnetic and superconducting materials.

Syllabus

I. Lectures on magnetism

1. Introduction, basic terms, Maxwell equations, magnetic moments (orbital, spin, nuclear), magnetic elements in the periodic table. Hydrogen atom, spin-orbit coupling.
2. Adding angular momentum operators (Clebsch-Gordan coefficients), Hund rules. Hyperfine interactions, atomic moments in an external magnetic field (classical and quantum approach), a set of localized magnetic moments, magnetic susceptibility.
3. Thermodynamic potentials, scheme of a thermodynamic procedure of calculating physical properties. Diamagnetism, theory of perturbation without degeneracy. Paramagnetism, theory of perturbation with degeneracy (quantum and classical approach).
4. Influence of a nonmagnetic surrounding on a magnetic ion, Crystalline Electric Field theory; cases of weak, strong and very strong CEF. Jahn-Teller effect.
5. Interactions between magnetic moments: exchange interactions (electrostatic, strong, short-range): direct, indirect (superexchange, double exchange, Dzyaloshinsky-Moriya, RKKY); dipol-dipol interactions (magnetic, weak, long-range).
6. Systems of coupled magnetic moments: basic models (Ising, Heisenberg, XY) , molecular field approximation, ferromagnetism, antiferromagnetism, helical order.
7. Magnetic domains: demagnetizing field, magnetic anisotropy, magnetostriction, formation of magnetic domains, domain walls, magnetization processes, hysteresis, permanent magnets; Two basic magnetic unit systems: CGS Gauss and SI.
8. Complex magnetic systems: superparamagnetism, spin glasses, frustration, magnetic "monopoles". Systems of strongly correlated electrons - Hubbard model, Kondo effect.
9. Gas of nearly free electrons in magnetic field. Landau diamagnetism (Landau quantization), Hall effect. Itinerant magnetism: Pauli susceptibility, Stoner model of ferromagnetism.
10. Phase transitions: classification (old by Ehrenfest and contemporary); critical phenomena; Landau theory of continuous (2^{nd} order) transitions; scaling hypothesis; renormalization group theory; universality classes; quantum phase transitions.

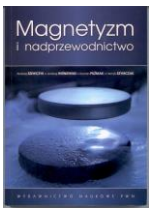
II. Lectures on superconductivity

11. Basic terms, phenomenological theory
    a. Main attributes of superconducting state (zero resistance, Meissner effect),

b. Model by Londons,
c. Superconductors of the I and II type,
d. Ginzburg-Landau theory (phase transitions in a system of non-uniform distribution of order parameter).

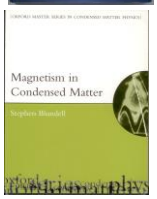
12. Elements of the BCS theory, order parameter, physical interpretation of the Ginzburg-Landau $\psi(x)$ function.
13. Magnetic flux quantization, vortex matter.
14. Josephson effect, SQUID magnetometers.
15. Overview of superconducting materials.

Literature:

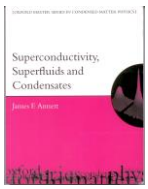


Magnetzm i nadprzewodnictwo,

A. Szewczyk, A. Wiśniewski, R. Puźniak, H. Szymczak



Magnetism in condensed matter, S. Blundell,



Suprconductivity, superfluids, and condensates, J.F. Annett

- *Fizyczne podstawy magnetyzmu* (*The Physical Principles of Magnetism)* H. Morrish
- *Kwantowa teoria magnetyzmu* (*Quantum theory of magnetism*), R.M. White
- *Wstęp do nadprzewodnictwa*, M. Cryot, D. Pavuna

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