

Contents of the exam

December 19, 2025

1 Description of the exam

We will give you around 10min to prepare a randomly picked question, and you should provide us a roughly 10 to 15min presentation on the blackboard. Your exposé will be followed up by questions, either on the selected topic or on the rest of the lectures/exercises. The exact derivations made in class are not crucial, but their main steps should be understood, and you should be able to explain them. You can bring with you two double-sided A4 sheets, either handwritten or in 10pt.

2 List of possible questions

2.1 Second quantization

1. What is second quantization? What are the main differences between bosonic and fermionic wavefunctions and their second quantized representations?
2. What is a Bogoliubov transformation? Describe the nature of the quasi-particles, as well as the groundstates.

2.2 Magnetism

1. How does (antiferro)magnetism emerges in a solid? What are the key ingredients to its existence?
2. Describe an effective model of ferromagnetism. What are the typical excitations and their properties at low-energy? What about finite temperature?

3. Same questions for an unfrustrated antiferromagnet.
4. What is frustration, and where does it come from? Quickly explain analytical approaches to such models, and the expected physics in the quantum and classical regimes.

2.3 Quantum Hall effect

1. What are Landau levels? Discuss their origin.
2. Why is conductance quantized in an integer quantum Hall state?
3. Discuss the Laughlin wavefunction at $\nu = 1/3$. What are the effective particles in such a model?

2.4 Superconductivity

1. Discuss the BCS approach of superconductivity.
2. What are the fundamental properties of a superconductor.
3. What is the difference between type 1 and type 2 superconductors?
4. What is the Ginzburg-Landau formalism?
5. What is the Josephson effect?