Superconductivity, superfluidity and Bose-Einstein condensation 1102-6‘BEC

summer term 2025-26

Krzysztof Byczuk

Institute of Theoretical Physics, Faculty of Physics, University of Warsaw
byczuk@fuw.edu.pl
`https://www.fuw.edu.pl/~byczuk/`

31-03-2026

Rules of passing

From each set of problems chose one and type complete answers with all explanations, details, literature and AI prompts and replies, in a form of an essay. Essays can be single, double or triple authors maximally. One version with all contributing authors should be send as pdf by e-mail on my address *byczuk@fuw.edu.pl*. Final grade will be proportional to the number of submitted essays and their qualities. To get 5! an oral exam is additionally required.

Lectures are on Thursdays at 11:15-12:00 in A2.11 room.

1 Preliminary Program

1. Quantum coherence on macroscopic scale
   (a) Introduction
   (b) Brief historical notes
   (c) Nobel prices
2. Bose-Einstein condensation
   (a) Standard description of Bose-Einstein condensation (BEC)
   (b) Symmetry and phase transitions
   (c) Off diagonal long range order in BEC
   (d) Coherent states in harmonic oscillator
   (e) BEC as a coherent state

2 Problem sets

1. Set one - BEC
   (a) Describe methods or trapping and cooling of alkali atom gases and the methods of observing the BEC.
   (b) describe an example how changing a model one can get type I, II and III BEC.
   (c) Describe BEC as a symmetry breaking phase transition in d-dimensional space with the dispersion relation

$$\epsilon_{\mathbf{k}} = \epsilon_0 |\frac{\mathbf{k}}{k_0}|^s,$$

with ϵ_0 energy constant, k_0 wave number constant. Find transition temperature T_c, heat capacity at constant volume C_V, pressure p, entropy S, and internal energy U as a function of temperature T.

3 Literature

- will be added soon