

Superconductivity and superfluidity

Superconductivity. Phenomenology. Ideal conductivity and the Meissner-Ochsenfeld effect. Type I and type II superconductors. Superconducting materials and superconducting mechanisms.

Phenomenological theories: Ginzburg-Landau theory and inhomogeneous superconductors. Gauge symmetry and symmetry breaking. Thermal fluctuations. Vortex matter.

Microscopic theories: BCS theory of superconductivity. Electron-phonon interaction. Cooper instability. Bethe-Goldstone equation. BCS wave function. Mean-field Hamiltonian. BCS energy gap and gap equation for anisotropic superconductors. Quasiparticle spectrum. Thermodynamics. Nambu formalism and Gor'kov equations. Effect of impurities. Selected predictions of BCS theory (including the Josephson effect), and applications.

Unconventional superconductors: basic experimental facts and open questions.

Superfluidity and condensed phases. Bose-Einstein condensation. BEC in ultracold atomic gases.

Superfluid ^4He . Flux quantization and vortices. Momentum distribution and quasiparticle spectrum. Rotons.

Gross-Pitaevskii equation. Inhomogeneous superfluids: turbulence in quantum fluids.

Superfluid ^3He and triplet order parameter.

Advanced and research topics. Critical fluctuations in two-dimensional superfluids. Vortex-antivortex pair unbinding and the Berezinskii-Kosterlitz-Thouless transition. Dual description of superconductivity.

Fluctuation effects on thermal and transport properties of high- T_c superconductors. Pseudogap.

From superconductivity to superfluidity: BCS-BEC crossover.

Competition of superconductivity with other electronic instabilities: ferromagnetism, electronic topological transitions, hidden orders.