

**Program for exam,  
Quantum Mechanics, part II, 2009**

Question marked by “ ? ” are NOT in the program.

**Relativistic equations**

**1. Klein-Gordon equation**

- Energy and momentum for relativistic particles
- Wave function of a free scalar particle
- Klein-Gordon equation for free scalar particles
- Gauge invariance
  - Gauge transformation of wave functions
  - Gauge transformation of the electromagnetic vector-potential
  - Covariant derivatives and gauge transformations
- Klein-Gordon equation for scalar particles in an external electromagnetic field
- Coulomb problem for scalar particles, Coulomb energies
- ? Charged scalar particles in a homogeneous magnetic field, Landau levels

**2. Dirac equation**

- Dirac spinors and matrixes
- Dirac equation for free fermions
- Reduction of the Dirac equation to the Klein-Gordon equation for free particles
- Energy spectrum of free fermions
- Negative energies and the Dirac sea, Fermi statistics for fermions
- Gauge invariance and the Dirac equation in an external electromagnetic field
- ? Dirac equation for electrons in a homogeneous magnetic field, Landau levels

**Scattering theory, Elastic scattering**

- Wave function of the scattering problem at large separations from the potential
- Scattering amplitude:
  - i. Definition via the asymptotic of the wave function
  - ii. Expression via the matrix element of the potential
- Current of the probability
- Differential and total cross sections, their expressions via the scattering amplitude
- Perturbation theory:
  - i. first Born approximation,
  - ii. applicability of the Born approximation at low and high energies
- Low-energy scattering

- i. scattering length
  - ii. differential and total cross section
- Low-energy resonance
  - i. Resonance due to a bound state with low binding energy
  - ii. ? Resonance due to a virtual energy level
- Partial-wave expansion:
  - i. Expansion of the wave function for free propagation
  - ii. Expansion of the wave function for scattering problem
  - iii. ? Schrödinger equation for radial wave functions
  - iv. Scattering phases
  - v. Scattering amplitude and the phases
  - vi. ? S-matrix
  - vii. Total cross section and phases
- Optical theorem
- ? Levinson's theorem
- ? Behaviour of the s-wave phase in a vicinity of the low-energy resonance
- ? Resonance levels, widths of resonances
- ? Scattering in the vicinity of resonances; resonant behaviour of the
  - i. ? S-matrix
  - ii. ? Scattering amplitude
  - iii. ? Phase
  - iv. ? Cross section