

Theoretical Physics V – Quantum Mechanics II

Winter Semester 2019/20

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Typical Exam Questions #1

Hand Out: 28 January 2020

Questions with *stars are based on material distributed for reading, but not covered in detail in the lecture.

Question 1.1 – Many-body theory (15 Points)

- What are annihilation and creation operators?
- Write the Hamiltonian of a many-body system in second quantisation
 - for an ideal gas,
 - for non-interacting electrons bound to an atomic nucleus,
 - for two-body interactions.
- Give an operator for the particle density.
- *In the Hartree-Fock theory, there is a quantity that is optimised using variational calculus. What is this quantity and what is the meaning of the parameters that are optimised/varied?
- Explain differences and similarities between fermions and bosons.
- What is the Fermi sphere? What is Fermi pressure?
- *What are the main ideas of BCS theory?

Question 1.2 – Relativistic quantum mechanics (15 Points)

- What the Klein-Gordon and Dirac equations?
- How can one interpret a Dirac spinor physically? Give examples for physical observables.
- What is the conserved current in the Dirac theory?
- What is minimal coupling?
- Give examples for successful predictions of the Dirac equation.
- Fermions or bosons?

- *What indications do we have that the Dirac equation actually describes a many-body problem (a quantum field theory)?
- Which problems arise with the Dirac (the Klein-Gordon) equation?
- *What is the connection between the Dirac and the Schrödinger (or Pauli) equation?

Question 1.3 – The Standard Model (15 Points)

- List the zoo of particles. Sketch the hierarchy of masses.
- What is a gauge theory?
- What are the gauge groups in the Standard Model?
- *Which symmetries (continuous, discrete) does the Dirac equation have?
- How does one formulate an extremal principle for fields? How does one get to a wave equation from there?
- What is a fundamental interaction? *What is the difference with effective interactions? Give examples.