**Exam "Foundations of Quantum Mechanics"**
**31 January 2012, 14.00-17.00 p.m.**

*Please write your name and registration number on every sheet!*

1. According to Bohr one cannot assign properties to a physical system independently of the measuring context. Changing the measuring context also implies changing the properties that can be attributed to the measured system.
   a. Illustrate these "Copenhagen" ideas by an analysis of the double-slit experiment.
   b. Discuss the relation between Bohr's ideas and the Kochen-Specker theorem.

2. Suppose that an object system O enters into an interaction with a measuring device M that has been designed to measure observable **A**.
   a. Explain how this measurement interaction (assumed to be ideal) should be described according to von Neumann.
   b. Explain why and how the final state of this interaction gives rise to the "measurement problem".
   c. In what way is this problem accommodated by the standard postulates of quantum mechanics?
   d. Discuss the pros and cons of this "standard solution" of the measurement problem.

3. In a variation on the Einstein-Podolsky-Rosen thought experiment one considers two particles, L and R, respectively, that are in the following total state:
   $|\Psi\rangle = 1/\sqrt{2}\ \{|a\rangle|b\rangle + |c\rangle|d\rangle\}$, in which $|a\rangle$ and $|c\rangle$ stand for two non-overlapping states of L that are localized at different positions in our laboratory, and $|b\rangle$ and $|d\rangle$ two non-overlapping R states localized at very distant positions. We are going to measure an observable of L of which $|a\rangle$ and $|c\rangle$ are eigenstates.
   a. If $|\Psi\rangle$ is the total state, what are the states of L and R, respectively (before measurement)?
   b. How would you describe the described measurement mathematically?
   c. Explain Einstein's argument for hidden variables in this context.

4. Einstein's hopes for a local hidden variables theory were (with hindsight) destroyed by Bell's theorem.
   a. Explain what Bell's theorem says and exactly what assumptions are made in its derivation.
   b. Can you think of a formulation of Bell's theorem that directly applies to the situation described in 3? Motivate your answer.

5. Try to give definitions of the following terms.
   a. Complementarity
   b. Pure state
   c. Density operator
   d. Contextuality
   e. Hidden variable