Exam Advanced Quantum Mechanics
23 August 2017

Name:.....

- Please write your answers on numbered pages. Write your name on each page. Start a separate page for each new question. Additional pages with your draft work, rough calculations or incomplete answers are handed in separately but are not considered.
- The exam is oral, closed book

Oral: Give clear and short answers to the following questions. Use drawings and formulae to explain better your words.

1. What is the experimental set-up and what are the experimental facts for the Aharanov-Bohm effect applied to the two-split experiment. What changes and how does that change as function of what?

2. In what sense is the Jaynes-Cummings model different from the semi-classical treatment of Rabi-oscillations? Different physics – different approximations? What is the physical context?

Written: write clearly.

3. We consider a spin 1 particle (give an example!). We pick a basis corresponding to the three eigenvectors of the z-component s_z, with eigenvalues $+1, 0, -1$ respectively. An ensemble is described by density matrix

$$\rho = \frac{1}{4} \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 2 \end{pmatrix}$$

Is that really a density matrix? [Check!] Is it describing a pure or a mixed state? What is the average value of s_z and what is the standard deviation?

4. Calculate for a complex number z,

$$e^{za^*}\, e^{-z^* a}\, |0\rangle$$

where, respectively, a and a^* are the annihilation and creation operator for the harmonic oscillator with ground state $|0\rangle$. Call $|n\rangle$ the eigenstate with n particles/photons.

5. Determine the Clebsch-Gordan coefficients associated with the addition of one spin 1/2 and one spin 1.