LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	MTF067
Examination date	2002-10-31
Time	09.00 - 14.00

Examination in: QUANTUM PHYSICS
Total number of problems: 5
Teacher on duty: Johan Hansson — Tel: 491072, Room E102a
Examiner: Johan Hansson — Tel: 491072, Room E102a
The results are announced: November 14, 2002 — on the notice-board, building E
The grading may be scrutinised: after the results have been announced

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Allowed aids: FYSIKALIA, PHYSICS HANDBOOK, *ANY* mathematical handbook (for example BETA), calculator, COLLECTION OF FORMULAE

Define notations and motivate assumptions and approximations. Present the solutions so that they are easy to follow. The maximum number of points is 15 p. 7 points is required to pass the examination (grade 3), 10.5 points for grade 4, 13 points for grade 5.

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1. a) What can you immediately conclude about the possible energies of any *bound* quantum mechanical system? (1p)

   b) What mathematical property of the Schrödinger equation is essential for the *superposition principle* in quantum mechanics? (1p)

   c) How can *more* ways for something to happen sometimes give *less* probability for it in quantum mechanics? (1p)

2. An electron in a hydrogen atom is in the state described by the wave function

$$\psi(\mathbf{r}) = \frac{1}{6}[4\psi_{100}(\mathbf{r}) + 3\psi_{211}(\mathbf{r}) - \psi_{310}(\mathbf{r}) + \sqrt{10}\psi_{410}(\mathbf{r})].$$

   a) What is the expectation value of the energy?

   b) What is the expectation value of $\mathbf{L}^2$?

   c) What is the expectation value of L_z? (3p)

3. An atom in the process of making a transition from an excited state (2) to the ground state (1) can, in a simplified model, be described by the wave-function

$$\Psi = c_1\psi_1(x)e^{-iE_1t/\hbar} + c_2\psi_2(x)e^{-iE_2t/\hbar}.$$

   a) Show that the probability density is oscillatory in time. (2p)

   b) Calculate the oscillation frequency and show that this gives the correct energy for the emitted photon. (Photon absorption is due to resonance between the atom and an incoming photon of this frequency.) (1p)

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4. a) Calculate the expectation value of the *potential energy* for the one-dimensional (quantum mechanical) harmonic oscillator.

   b) Show that the expectation value for the *kinetic energy* is equal to the result in a). (3p)

5. a) Calculate the position where the radial probability density for the ground state of Hydrogen has its maximum. (2p)

   b) Write down the expectation value of r for a Hydrogen atom known to be in its ground state. Why is this not identical to the answer in a)? (1p)

GOOD LUCK !