LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	MTF067
Examination date Time	2001-12-17 09.00 - 14.00

Examination in: QUANTUM PHYSICS
Total number of problems: 5
Teacher on duty: Johan Hansson Tel: 910 72, Room E102a
Examiner: Johan Hansson Tel: 910 72, Room E102a
The results are announced: 21 December 2001 on the notice-board, building E
The grading may be scrutinised: after the results have been announced

Allowed aids: FYSIKALIA, BETA, calculator, COLLECTION OF FORMULAE

Define notations and motivate assumptions and approximations. Present the solutions so that they are easy to follow. Maximum number of points is 15 p. 7 points (including bonus) is required to pass the examination.

1. Show, by explicit calculation, that any spherical harmonic (arbitrary l and m) is an eigenfunction of L_z. What are the possible eigenvalues, and what is their physical interpretation? (2p)

2. Calculate the expectation values $\langle x \rangle$ and $\langle x^2 \rangle$ for any given eigenfunction of a one-dimensional (quantum mechanical) harmonic oscillator. (3p)

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

$$\psi(\mathbf{r}) = \frac{1}{6}[4\psi_{100}(\mathbf{r}) + 3\psi_{211}(\mathbf{r}) - \psi_{210}(\mathbf{r}) + \sqrt{10}\psi_{21-1}(\mathbf{r})].$$

a) What is the expectation value of the energy? (1p)

b) What is the expectation value of $\mathbf{L}^2$? (1p)

c) What is the expectation value of L_z? (1p)

4. The spin-part of a spin-1/2 quantum mechanical system is given by

$$\chi = \frac{1}{\sqrt{5}}(2|\uparrow\rangle + i|\downarrow\rangle).$$

a) Show that $\mathbf{S}^2$ and S_z commute. (1p)

b) What are the possible eigenvalues of $\mathbf{S}^2$ and S_z? Are they simultaneously measurable? (1p)

c) Calculate the probabilities for obtaining these eigenvalues. (1p)

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5. An electron is in the ground state of tritium ^3H. A β-decay instantaneously changes the atom into a helium ion $^3He^+$.

   (a) Calculate the probability that the electron is in the 2s-state ($n = 2$, $l = m = 0$) after the decay. (2p)

   (b) Calculate the probability that the electron is in a 2p-state ($n = 2$, $l = 1$) after the decay. (2p)

GOOD LUCK !