LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	MTF067
Examination date	2002-08-29
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: September 6, 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, 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. Using the operators S_x, S_y, S_z, show (by explicit calculation) that:
   a) $\mathbf{S}^2$ is simultaneously measurable with *any* of the S_x, S_y, S_z.
   b) Only *one* of the S_x, S_y, S_z can be measured at any one time. (3p)

2. The spin-part of a spin-1/2 quantum mechanical system is given by
$$\chi = N(3|\uparrow\rangle + i|\downarrow\rangle).$$
   a) What are the eigenvalues of S_z?
   b) Calculate the probabilities for obtaining these different eigenvalues.
   c) Calculate the expectation value of S_z. (3p)

3. 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)

4. 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?
   b) What is the expectation value of $\mathbf{L}^2$?
   c) What is the expectation value of L_z? (3p)

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5. A particle in a spherically symmetric potential is in a state described by the wave packet

$$\psi(x, y, z) = C(xy + yz + zx)e^{-\alpha r^2}$$

What is the probability that a measurement of the square of the angular momentum yields 0? What is the probability that it yields $6\hbar^2$? If the value of l is found to be 2, what are the relative probabilities for $m = 2, 1, 0, -1, -2$? (3p)

GOOD LUCK !