LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	MTF107
Examination date	2003-12-19
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: January 7, 2004 — on the notice-board, building E
The grading may be scrutinised: after the results have been announced

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Allowed aids: Physics Handbook, *ANY* mathematical handbook (for example BETA), calculator

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Define notations and motivate assumptions and approximations. **You must 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. In a double-slit experiment with neutrons the wave function corresponding to a route through slit one is ψ_1, and through slit two it is ψ_2. Show *mathematically* (with formulas) and explain *physically* the difference in the probability distribution of N hits on the detector screen between:

   i) First only one slit open (N/2 hits) then only the other (N/2 hits).

   ii) Both slits open at the same time (N hits). (3p)

2. Derive normalized eigenstates, for spin-1/2 particles, to the spin-operator

$$S_x \cos\theta + S_y \sin\theta$$

(3p)

3. Show that the *probability conservation law*

$$\frac{\partial P}{\partial t} + \frac{\partial j}{\partial x} = 0$$

follows from the one-dimensional Schrödinger equation with a (real) potential.

The probabliity current is defined as $j = \frac{\hbar}{2im}[\psi^* \frac{\partial \psi}{\partial x} - \psi \frac{\partial \psi^*}{\partial x}]$. (3p)

4. An electron in an oscillating electric field is described by the Hamiltonian

$$H = \frac{p^2}{2m} - x\, e\, E_0 \ \cos(\omega\, t) = 0.$$

Calculate $d\langle x\rangle/dt$, $d\langle p\rangle/dt$ and $d\langle H\rangle/dt$. (3p)

5. A particle is described by the normalized wavefunction given by: $\psi(x) = 2\alpha\sqrt{\alpha}\, x e^{-\alpha x}$ for $x > 0$; and $\psi(x) = 0$ for $x < 0$.

   a) For what value of x does the probability density peak?

   b) Calculate $\langle x\rangle$ and $\langle x^2\rangle$. (3p)

GOOD LUCK !