

QSIT 2010 - Questions 1

6. Oktober 2010

1. **State Space in Quantum Mechanics** What is the relevant Hilbert space that represents the dynamics of the following systems. Write down their basis states.

- (a) Two neutrons in a static magnetic field.
- (b) Two neutrons in a magnetic gradient field.
- (c) A small mirror attached to a spring.
- (d) A small mirror attached to a spring exposed to laser radiation .
- (e) A ground-state hydrogen atom at room temperature.
- (f) A hydrogen atom excited to the state $n = 60$ at room temperature.
- (g) A ground-state hydrogen atom exposed to laser radiation at a wavelength of 121 nm.
- (h) An ensemble of N hydrogen atoms in the ground state at room temperature.

2. **Bloch Sphere** Any quantum state of a spin-1/2 (or two-level system) can be represented on the *Bloch sphere*. Calculate the polar and azimuthal angles of the following states and draw the states on the Bloch sphere.

- (a) $|\psi\rangle = \frac{1}{\sqrt{3}} (|0\rangle + \sqrt{2}|1\rangle)$
- (b) $|\psi\rangle = \frac{1}{\sqrt{3}} (|0\rangle - i\sqrt{2}|1\rangle)$
- (c) $|\psi\rangle = \frac{e^{i\pi/4}}{\sqrt{3}} (|0\rangle - i\sqrt{2}|1\rangle)$

3. Rabi Oscillations

A spin-1/2 particle is placed in a magnetic field of magnitude B_z pointing in the z -direction. At time t_0 an additional field B_x is applied in the x -direction. Calculate the expected excited state population as a function of time and draw a diagram. Assume that $B_x \gg B_z$ and that the particle is initially in its ground state. What changes, if the additional magnetic field points in the y -direction instead?