

# QSIT 2012 - Questions 1

2. March 2012, HIT F 13

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) A neutron in a static magnetic field.
- (b) A neutron 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 ground-state hydrogen atom exposed to laser radiation at a wavelength of 121 nm.
- (g) 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)  $|\psi\rangle = \frac{1}{\sqrt{3}} (\sqrt{2}|0\rangle - i2|1\rangle)$
- (d)  $|\psi\rangle = \frac{e^{i\pi/4}}{\sqrt{3}} (|0\rangle - i\sqrt{2}|1\rangle)$

### 3. The no-cloning theorem

Prove that exact copying of an arbitrary state is not possible.

### 4. 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?