Technische Universität München **Theoretische Physik T70**
Physik Department **B. Garbrecht**
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Quantum Mechanics II

Winter Term 2015/16

Hand in until Thursday, 05.11.15, 12:00 next to PH 3218.

Exercise Sheet No. 03 To be discussed from 09.11. - 13.11.15.

Problem 1: Harmonic Oscillator in an External Field **5 Points**

Consider two charged particles in a bound state. For small displacements with respect to each other the potential in the relative coordinate x can be approximated by a parabolic, i.e. the Hamiltonian H_0 is that of a harmonic oscillator with mass m and frequency ω_0. Now the system is placed in an oscillating external electric field, which we characterize by a time dependent perturbation

$$V(t) = \Phi_0 x \cos(\omega t)\,. \tag{1}$$

Calculate the electric dipole moment $\langle\psi|qx|\psi\rangle$ with charge q to first order perturbation theory assuming that at initial time the system is in an energy eigenstate of H_0 and the perturbation is switched on at $t = 0$.

Problem 2: Hydrogen Atom in a Changing Electric Field **5 Points**

Consider a hydrogen atom in the ground state in the infinite past ($t \to -\infty$). It is exposed to a homogeneous electric field $\mathbf{E}(t) = (0, 0, E(t))$ with

$$E(t) = \frac{B\tau}{\pi e}\frac{1}{\tau^2 + t^2}. \tag{2}$$

Calculate the probability that the atom is in the $2p$ state at $t \to \infty$ by using lowest order perturbation theory.

Hint: The 1s wave function is given by

$$\psi_{1s} = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2} e^{-r/a_0}\,, \tag{3}$$

the wave functions in the 2p state are given by

$$\psi_{2p,m=0} = \frac{1}{4\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{3/2}\frac{r}{a_0}e^{-r/2a_0}\cos\theta\,, \tag{4}$$

$$\psi_{2p,m=\pm1} = \frac{1}{8\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2}\frac{r}{a_0}e^{-r/2a_0}\sin\theta e^{\pm i\phi}\,. \tag{5}$$

Here a_0 is the Bohr radius and r, θ, ϕ are polar coordinates.