RPTU KAISERSLAUTERN-LANDAU
Department of Physics

Winter Term 2023/2024
Priv.-Doz. Dr. Axel Pelster

Quantum Mechanics II — Problem Sheet 5

Problem 11: Harmonic Oscillator in an Electric Field: Instantaneous Perturbation (6 points)

A particle of mass M and charge q is subject to harmonic oscillations of frequency ω along the x-axis. It is suddenly placed in a uniform electric field that generates the potential $V(x) = -qEx$.

a) Determine the transition probabilities in the case in which the system is initially in the ground state.

b) Use first-order perturbation theory to approximate these probabilities in the case of a weak electric field.

Problem 12: Harmonic Oscillator: Gaussian Perturbation (6 points)

Consider a one-dimensional harmonic oscillator in the ground state at time $t = -\infty$ in the presence of the perturbation $V(x,t) = -qExe^{-t^2/\tau^2}$.

What is the probability of finding at $t = +\infty$ the oscillator in state $|n\rangle$ in first-order perturbation theory?

Problem 13: Harmonic Oscillator: Damped Perturbation (6 points)

Starting from the instant $t = 0$, the perturbation $V(x,t) = Ax^2e^{-bt}$ acts on a harmonic oscillator of mass M and frequency ω.

Use first-order perturbation theory and determine the probabilities of transition from the ground state to the nth state after a long period of time.

Problem 14: Hydrogen Atom in a Pulsed Electric Field (6 points)

At time $t = -\infty$, a Hydrogen atom is in the ground state. Then a time-dependent electric field is applied along the z-axis: $\mathbf{E}(t) = E_0e^{-t^2/\tau^2}\mathbf{e}_z$.

Determine the probability that at time $t \to +\infty$ the atom is in one of the $n = 2$ states by applying first-order perturbation theory.

Drop the solutions in the post box on the 5th floor of building 46 or, in case of illness/quarantine, send them via email to jkrauss@rhrk.uni-kl.de until December 4 at 11.45.