UNIVERSITÄT LEIPZIG

Experimental Physics IV IPSP

Problem Set 9

Deadline: Thursday, 13.06.2012, before the seminar

Problem 28: 3+2 points

The excited state of an electron decays exponentially with a certain life time τ by emitting a photon:

$$A(t) = e^{-|t|/\tau} .$$

a) Calculate the shape of the spectral intensity $F(\omega)$ of an emitted photon by using Fourier transformation.
b) Calculate the half width frequency $\omega_{1/2}$ where the spectral intensity drops to $\frac{1}{2}F_{\max}$.

Problem 29: 5 points

Electrons that were accelerated by an electrical field hit a hydrogen atom. The electron of the hydrogen atom is in its groundstate.

What acceleration voltage is necessary in order to transfer the minimal possible energy to the electron of the hydrogen atom? What voltage is needed for ionizing the hydrogen atom?

Problem 30: 2+2 points

Derive the Klein-Gordon equation using the relativistic energy $E = \sqrt{m^2c^4 - p^2c^2}$ and the quantummechanical energy and momentum operators.

Give either a short interpretation of the Klein-Gordon equation or name some problems of this equation or some properties. You can choose one or more of these options.

Problem 31: 3+1 points

Calculate the following commutators: $[\vec{p}, \vec{x}]$, $[E, p_x]$, $[p_x, H]$ with $[a, b] = ab - ba$, $\vec{p} = -i\hbar\nabla$ $E = i\hbar\frac{\partial}{\partial t}$ and $H = -\frac{\hbar^2\nabla^2}{2m} + V(x)$. Why are commutators important?

Hint: Remember that all operators act on wavefunctions, so that: $[\overrightarrow{p}, \vec{x}] := [\overrightarrow{p}, \vec{x}]\Psi(x, t)$