Physics 4410
Quantum Mechanics 2

Lecture 29

The Zeeman effect

November 4, 2020

1. Summarize the hydrogen atom fine structure.

Activity 1: Zeeman effect in non-relativistic hydrogen. Consider the hydrogen atom (include electron spin) in a magnetic field:

$$H = \underbrace{\frac{\mathbf{p}^2}{2m_{\mathrm{e}}} - \frac{e^2}{4\pi\epsilon_0 r}}_{H_0} + B\left(g_1 L_z + g_2 S_z\right).$$

What are the energy levels of H?

Activity 2: Zeeman effect in the 1s state.

(a) Consider the hydrogen atom in the 1s state, and in a magnetic field. In terms of the electron spin $\mathbf{S}$ and the proton spin $\mathbf{I}$, we can approximate

$$H = A\mathbf{S} \cdot \mathbf{I} + gBS_z.$$

What are the eigenvalues/eigenvectors of H when $g = 0$?

(b) Use degenerate perturbation theory to find the eigenvalues/eigenvectors to first order in g.

(c) Use degenerate perturbation theory to find the eigenvalues/eigenvectors to second order in g.

(d) Solve for the eigenvalues exactly, and compare to perturbation theory.