PHYS 5002: Homework 8

1 Parity violating interaction

Consider a hypothetical parity violating interaction

$$\hat{V}' = \lambda\hbar\frac{\mathbf{S}\cdot\mathbf{r}}{r}$$

added to the hydrogen atom Hamiltonian. The symbol λ is the strength of the interaction. Consider how it affects the $n = 2$ energy levels, but neglect the fine structure. So $\hat{H} = \hat{H}_0 + \hat{V}'$ where

$$\hat{H}_0 = \frac{\hat{p}^2}{2\mu} - \frac{Ze^2}{\hat{r}}$$

where Z is the atomic number and μ is the reduced mass.

To first order in $\hat{V}'$ compute the energy levels and degeneracies of $\hat{H}$ for the case $n = 2$. (Note that Z is not necessarily 1 here).

HINT: Think of which operators commute with $\hat{H}$.

2 Two spin-half particles

A system of two "nailed-down" spin-$\frac{1}{2}$ particles are described by

$$\hat{H} = A\mathbf{S}_1\cdot\mathbf{S}_2 + BS_1^z.$$

a.) Compute the energy levels exactly.
b.) Treat BS_1^z as a perturbation. Find the unperturbed energy levels E_n^0. Find the perturbed levels through second order in S. Compare the exact to the perturbed results by using a Taylor expansion.

3 Sequel to problem 2 from HW#7

Suppose the matrix V^k also vanishes at second order. Show that $|k, n_k\rangle_{\parallel}^{(3)}$ can be found in third order and that the energy shifts are found from

$$\det\left(\hat{P}_k\hat{V}\frac{\hat{Q}}{E_k^0 - \hat{H}_0}\hat{V}\frac{\hat{Q}}{E_k^0 - \hat{H}_0}\hat{V}\hat{P}_k - E_k^{(3)}\hat{P}_k\right) = 0.$$