

PHYS 622: Quantum Mechanics II
Due date: Thursday, February 6, 2014

Problem Set #3

Sakurai and Napolitano problems:
5.10 [5.10], 5.16 [5.16]

The old (red) Sakurai (revised, 1st ed.) problems are listed in brackets.

The $2S_{1/2}$ and $2P_{1/2}$ levels of hydrogen

Consider the following Hamiltonian for the hydrogen atom

$$H = H_0 - \frac{P^4}{8m_e^3c^2} + \frac{1}{2} \frac{e^2}{m_e^2c^2} \frac{1}{R^3} \vec{L} \cdot \vec{S} \quad \text{with} \quad H_0 = \frac{P^2}{2m_e} - \frac{e^2}{R}$$

(We will not consider the Lamb shift in this problem)

- Determine the 0th order correction to the eigenstates (i.e. identify a suitable basis which diagonalizes this Hamiltonian) starting from the eigenstates of H_0 .
- Compute the 1st order correction to the eigen-energies of H_0 corresponding to the $2S_{1/2}$ and $2P_{1/2}$ states.