

Physics 521 – Graduate Quantum Mechanics
Homework VII, due Wednesday, March 5, 2008 at 8:30 a.m.

1. Reading

G&Y Chapter 6

2. Atomic and Molecular Hydrogen

The wavefunction for a system of two hydrogen atoms can be described approximately in terms of hydrogenic wavefunctions.

(a) Give the complete wave functions for the lowest states of the system for singlet and triplet spin configurations. Sketch the spatial part of each wave function along a line through the two atoms.

(b) Sketch the effective potential energy for the atoms in the two cases as functions of the internuclear separation (neglect rotation of the system). Explain the physical origin of the main features of the curves, and of any differences between them.

3. Interacting Fermions in a 1D Square Well

Two identical nonrelativistic fermions of mass m and spin $1/2$ are in a one dimensional square well of length L , with V infinitely large and repulsive outside the well. The fermions are subject to a repulsive inter-particle potential $V(x_1 - x_2)$, which may be treated as a perturbation. Classify the three lowest-energy states in terms of the states of the individual particles and state the spin of each. Calculate, to first order in perturbation theory, the energies of second- and third-lowest states; leave your result in the form of an integral. Neglect spin-dependent forces throughout.

4. Statistics Comparisons

Two particles of mass m are placed in a rectangular 3D box of sides $a > b > c$ in the lowest energy state of the system compatible with the conditions below. The particles have a contact interaction, $V = A\delta(\vec{r}_1 - \vec{r}_2)$. Use first order perturbation theory to calculate the energy of the system under the following conditions:

- (a) Particles not identical;
- (b) Identical particles of spin zero;
- (c) Identical particles of spin one-half with spins parallel.