Physics 203

Homework 4

1.) The central part of the nucleon-nucleon potential can be written as a sum of four terms:

$$V(r) = -V_0[W(r) + B(r)\hat{P}_\sigma + M(r)\hat{P}_x + H(r)\hat{P}_x\hat{P}_\sigma]$$

where $\hat{P}_\sigma$ is the spin exchange operator and $\hat{P}_x$ is the space coordinate exchange operator. Using the symmetry properties of the spin-singlet and triplet S and P states, determine the relation between the above interactions (W, B, M, H) and the four interactions: $V_{1S}(r), V_{3S}(r), V_{1P}(r), V_{3P}(r)$; corresponding to the nucleon-nucleon potentials with the nucleons in ^1S, ^3S, ^1P, ^3P states respectively.

2.) Supplemental Problem 2 (SP2).

3.) Supplemental Problem 3 (SP3).

4.) Show that a N-N potential for the deuteron containing a tensor term of the form

$$\hat{S}_{12} = (\frac{3}{r^2})(\hat{\boldsymbol{\sigma}}_1 \cdot \hat{\mathbf{r}})(\hat{\boldsymbol{\sigma}}_2 \cdot \hat{\mathbf{r}}) - \hat{\boldsymbol{\sigma}}_1 \cdot \hat{\boldsymbol{\sigma}}_2$$

can produce a mix of $S-$ and $D-$states by calculating the effect of the $\hat{S}_{12}$ operator on the two-nucleon angular momentum states with $L = 0$ and $L = 2$ for $J = 1$ and $S = 1$ fixed (i.e. $^3S_1, ^3D_1$). [Hint: Show that

$$\hat{S}_{12}|^3S_1 >= \alpha|^3D_1 > +\beta|^3S_1 >, \text{and}$$

$$\hat{S}_{12}|^3D_1 >= \gamma|^3D_1 > +\delta|^3S_1 >$$

by determining the coefficients $\alpha, \beta, \gamma, \delta$.]

5.) For a non-local potential $\hat{V}(\mathbf{r}, \mathbf{r}')$, the potential energy operator $\hat{V}$ acting on the wave function ψ is

$$\int \hat{V}(\mathbf{r}, \mathbf{r}')\psi(\mathbf{r}')d^3r'.$$

Show that such a non-local potential is equivalent to a momentum (and hence velocity-) dependent potential. [Hint: consider momentum space transforms.]