PHYS 560: Assignment 2

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Abstract

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Let us imagine that the nuclear interaction is caused by the exchange of a spinless particle of mass equal to that of the pion, giving rise to an isospin independent potential

$$V(r) = -\alpha \frac{e^{-m_\pi r}}{r} \quad . \tag{1}$$

We will choose alpha to be $\alpha = 0.069934$, a number that we will find out more about later in the course. We wish to consider a single nucleon incident upon a single nucleon at rest in the lab frame. Let the incident nucleon have kinetic energy $T_{\rm lab}$. Assume that the nucleons are interacting in the $S = 0$ (total spin=0 channel to compare with data.

1. Find the wavefunctions

   $$\psi(\mathbf{r}) = \frac{1}{r} U_l(r) Y_{lm}(\Omega) \quad , \tag{2}$$

   for this potential and plot $U_l(r)$ as a function of r on the same plot as the the corresponding wavefunction for the system with NO potential, $V(r) = 0$ everywhere, for each different $l = 0, 1, 2, 3, 4$.

2. Plot the radial wavefunctions for each different l on the same plot.

3. Determine the scattering length.

4. Determine the phase shifts δ_l for $l = 0, 1, 2, 3, 4$ for incident nucleon energy between 0 and 100MeV. Plot these phase shifts in degrees as a function of energy.

5. Compare these with the experimental data that you will have to find somewhere in the library or on the net at http://nn-online.sci.kun.nl/NN/NNonline.html

6. Discuss the reasons for agreement or disagreement, depending on what you find for each partial wave.

[NOTE: You will need to use Mathematica for this. The schrodinger equation should be solved numerically using NDSolve, which you can read about in the book. The plots should be generated by the same program. You will need to determine the boundary conditions of the wavefunction at small r (but not $r = 0$ as Mathematica can't handle that). You will need the value and slope.]

Also note, that this potential is not a true description of nuclear interactions as you might have guess, but you can judge for yourself how well it works.