Building a Shell Model Code: The Pairing Model and the sd-Shell

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July 18, 2017

Abstract

We have first implemented the pairing model which have a analytical solution (to benchmark the code). Then implemented the sd shell —> more general shell-model program that allows you to study general nuclear structure problems.

We have also used the NushellX code in order to perform more advanced shell-model studies and compare the results obtained with your own shell-model code to those of NushellX

I. Introduction

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II. Theory

i. The Pairing Model

The pairing model is one of a few systems that has a simple analytic solution. It is therefore very useful to use this model to check that the numerical solution matches the analytic solution while developing the code.

The pairing problem consists of a system where the fermions combines together in pairs of two, one with spin up and one with spin down. This model does not allow so-called 'breaking of pairs' meaning that the pairs of particles always will be coupled together. An excitation must excite both particles of the pair to create new excited states.

Mathematically the pairing model can be described by a simplified Hamiltonian consisting of a unperturbed one-body operator H^0 and a pertubation so-called 'pairing interaction term' H^I. We will limit ourselves to at most two-body interactions so that we can write the operators as:

$$\hat{H}_0 = \xi \sum_{p,\sigma} (p-1) \hat{a}^\dagger_{p\sigma} \hat{a}_{p\sigma}, \tag{1}$$

$$\hat{V} = -\frac{1}{2} g \sum_{p,q} \hat{a}^\dagger_{p+} \hat{a}^\dagger_{p-} \hat{a}_{q-} \hat{a}_{q+}, \tag{2}$$

so that the full Hamiltonian is given by the sum of the unperturbed term and the interacting part $\hat{H} = \hat{H}_0 + \hat{V}$. The fermion creation and annihilation operators are given by $\hat{a}^\dagger_p$ and $\hat{a}_q$ respectively and *pqrs* represent all possible single-particle quantum numbers. To simplify the expressions we set the spacing between successive single-particle states given by $\xi = 1$.

We will let the single-particle states$|p\rangle$ be eigenfunctions of the one-particle operator $\hat{h}_0$. The above Hamiltonian acts in turn on various many-body Slater determinants constructed from the single-basis defined by the one-body operator $\hat{h}_0$.

The two-body operator $\hat{V}_0$ has one term only. It represents the pairing contribution and carries a constant strength g and is given by

Table 1: *Example table*

Name		
First name	Last Name	Grade
John	Doe	7.5
Richard	Miles	2

The analytical solutions for P=4 We are only including two lowest single-particle levels and totally two particles. We want to construct the Hamiltonian matrix using second quantization and WickâĂŹs theorem for a system with no broken pairs and $S = 0$, $S_z = 0$

In this model we can only excite two particles at the same time, so we can define the ground state and the excited state which are the only two possible states:

(also include a figure with the states drawn?)

III. Methods

Text requiring further explanation[1].

IV. Results

V. Discussion

References

[Figueredo and Wolf, 2009] Figueredo, A. J. and Wolf, P. S. A. (2009). Assortative pairing and life history strategy - a cross-cultural study. *Human Nature*, 20:317–330.

[Github of the TALENT School] HJ and Alex Brown *link goes here*,

[1]Example footnote