This is a template Article - lets fill in on the way as we finish parts

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Abstract

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I. INTRODUCTION

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*A thank you or further information - fill in
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II. Part 1 - rename sections later, do not need the numbering of the exercises

i. Exe. 1a

Show that the unperturbed Hamiltonian $\hat{H}_0$ and $\hat{V}$ commute both with $\hat{S}_z$ and $\hat{S}^2$.

$$\hat{H}_0 = \Sigma_{p\sigma}(p-1)a^{\dagger}_{p\sigma}a_{p\sigma}\hat{S}_z = \frac{1}{2}\Sigma_{pq}\sigma a^{\dagger}_{p\sigma}a_{p\sigma}$$

first rewriting the products:

$$\begin{aligned}
\hat{S}_z\hat{H}_0 &= \frac{1}{2}\Sigma_{p\sigma}\sigma a^{\dagger}_{p\sigma}a_{p\sigma} \cdot \Sigma_{p\sigma}(p-1)a^{\dagger}_{p\sigma}a_{p\sigma} \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{p\sigma}a_{p\sigma}a^{\dagger}_{qb}a_{qb} \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{\alpha}a_{\alpha}a^{\dagger}_{\beta}a_{\beta} \\
\hat{H}_0\hat{S}_z &= \Sigma_{p\sigma}(p-1)a^{\dagger}_{p\sigma}a_{p\sigma} \cdot \frac{1}{2}\Sigma_{p\sigma}\sigma a^{\dagger}_{p\sigma}a_{p\sigma} \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{qb}a_{qb}a^{\dagger}_{p\sigma}a_{p\sigma} \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{\beta}a_{\beta}a^{\dagger}_{\alpha}a_{\alpha}
\end{aligned}$$

so that the commutation relation becomes:

$$\begin{aligned}
[\hat{S}_z, \hat{H}_0] &= \hat{S}_z\hat{H}_0 - \hat{H}_0\hat{S}_z \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{\alpha}a_{\alpha}a^{\dagger}_{\beta}a_{\beta} - \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)a^{\dagger}_{\beta}a_{\beta}a^{\dagger}_{\alpha}a_{\alpha} \\
&= \frac{1}{2}\Sigma_{p\sigma}\Sigma_{qb}\sigma(q-1)\left(a^{\dagger}_{\alpha}a_{\alpha}a^{\dagger}_{\beta}a_{\beta} - a^{\dagger}_{\beta}a_{\beta}a^{\dagger}_{\alpha}a_{\alpha}\right)
\end{aligned}$$

which can only be zero if

$$a^{\dagger}_{\alpha}a_{\alpha}a^{\dagger}_{\beta}a_{\beta} - a^{\dagger}_{\beta}a_{\beta}a^{\dagger}_{\alpha}a_{\alpha} = 0$$

we can use the relations

$$\begin{aligned}
\hat{a}^{\dagger}_i\hat{a}^{\dagger}_j &= -\hat{a}^{\dagger}_j\hat{a}^{\dagger}_i \\
\hat{a}_i\hat{a}_j &= -\hat{a}_j\hat{a}_i \\
\{\hat{a}^{\dagger}_i, \hat{a}_j\} &= \hat{a}^{\dagger}_i\hat{a}_j + \hat{a}_j\hat{a}^{\dagger}_i = \delta_{ij} \\
\Rightarrow \hat{a}^{\dagger}_i\hat{a}_j &= -\hat{a}_j\hat{a}^{\dagger}_i, i \neq j
\end{aligned}$$

to rewrite the first expression

$$
\begin{aligned}
a_\alpha^\dagger a_\alpha a_\beta^\dagger a_\beta &= a_\alpha^\dagger a_\beta^\dagger a_\alpha a_\beta \\
&= -a_\beta^\dagger a_\alpha^\dagger a_\alpha a_\beta \\
&= -a_\beta^\dagger a_\alpha^\dagger (-a_\beta a_\alpha) \\
&= a_\beta^\dagger a_\alpha^\dagger a_\beta a_\alpha \\
\Rightarrow & a_\alpha^\dagger a_\alpha a_\beta^\dagger a_\beta - a_\beta^\dagger a_\beta a_\alpha^\dagger a_\alpha = 0 \\
\Rightarrow & [\hat{S}_z, \hat{H}_0] = 0
\end{aligned}
$$

hmmm is this really a proof? indices

ii. Exe. 1b - simple model

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

Maecenas sed ultricies felis. Sed imperdiet dictum arcu a egestas.

- Donec dolor arcu, rutrum id molestie in, viverra sed diam
- Curabitur feugiat
- turpis sed auctor facilisis
- arcu eros accumsan lorem, at posuere mi diam sit amet tortor
- Fusce fermentum, mi sit amet euismod rutrum
- sem lorem molestie diam, iaculis aliquet sapien tortor non nisi
- Pellentesque bibendum pretium aliquet

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Text requiring further explanation[1].

Table 1: *Example table*

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

IV. Results

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$$e = mc^2 \tag{1}$$

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V. Discussion

i. Subsection One

A statement requiring citation [Figueredo and Wolf, 2009]. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

[1] Example footnote

ii. Subsection Two

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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.