

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

[YOUR NAMES FIX LATER], INA K. B. KULLMANN*

JANE SMITH[†]

University of Oslo
i.k.b.kullmann@fys.uio.no

University of Utah
jane@smith.com

July 7, 2017

Abstract

Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

I. INTRODUCTION

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

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 .

*A thank you or further information - fill in

[†]Corresponding author

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

first rewriting the products:

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

so that the commutation relation becomes:

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

which can only be zero if

$$a_\alpha^\dagger a_\alpha a_\beta^\dagger a_\beta - a_\beta^\dagger a_\beta a_\alpha^\dagger a_\alpha = 0$$

we can use the relations

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

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 Wick's theorem for a system with no broken pairs and $S = 0$, $S_z = 0$

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

Lorem ipsum dolor sit amet, consectetur 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,

Table 1: *Example table*

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

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.

Text requiring further explanation¹.

IV. RESULTS

Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

$$e = mc^2 \quad (1)$$

Lorem ipsum dolor sit amet, consectetur 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

¹Example footnote

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, consectetur 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.

V. DISCUSSION

i. Subsection One

A statement requiring citation [Figueredo and Wolf, 2009]. Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

ii. Subsection Two

Lorem ipsum dolor sit amet, consectetur 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, consectetur 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.

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.