Advanced quantum mechanics (20104301)

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Chapter 0: Introduction

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Introduction

0.1 An introductory word

This course will be concerned with quantum theory, the fundamental theory of nature. Properties of condensed matter systems, of atoms, molecules and basically the world surrounding us cannot be understood without resorting to quantum mechanics. The advent of quantum mechanics constitutes the most radical break from classical mechanics as it was developed until the end of the 19th century. The fact that quantum mechanics is an intrinsically statistical theory that does not allow for an interpretation in terms of classical probability theory is one one of the features of quantum theory in which it is departing from classical physics.

Building upon what we have learned in the first course on quantum mechanics, we will now be concerned with advanced topics. In this endeavour, we will spend a lot of time with dealing with the situation in which *many particles* of the same kind come together. This is for a good reason: After all, this is the situation commonly encountered when thinking of actual materials, of solid bodies of systems are they are commonly studied in statistical mechanics. We will encounter intriguing quantum phenomena of conductors having no resistance – so-called superconductivity – and fluids with no viscosity – superfluid. We will have a look at properties of interacting quantum systems that cannot be explained by just looking at its parts. There, we will investigate some truly advanced topics, related to tensor network descriptions of quantum many-body systems. How is this possible? We will see that *structure* is the key.

Understanding structure in quantum many-body theory: We will see that a lot of quantum many-body theory can be understood by appreciating the underlying structure that is present in the system. In fact, a lot of the phenomenology of quantum many-body theory can be grasped in terms of so-called non-interacting models, even if interactions are present in the microscopic underlying model. If that fails, one can still resort to structures such as tensor networks.

At this point, this must sound very much cryptic. But do not worry, it will be the point of the course to explain what that means. Before coming to that, however, we will quickly resume the basics of quantum mechanics as such. This will be brief, but do not worry too much: It will all be content that has been treated in great detail in the first course anyway.

How to use these lecture notes: It is the point of these lecture notes to summarize the content of the course. Important definitions or results will be highlighted using boxes that look like this.

These lecture notes will be dynamically evolving along with the course and are not set in stone. This comes along with the advantage that not even the course content is fully set in stone, there is some flexibility here. The course is not based on any specific book. Having said that, here and there I am shamelessly copying content from other sources, if I think this to be appropriate (but of course, credit is given then). The lecture notes are strictly meant to be of good use concomitant with the lecture. They are no draft for a book in the making, they are raw and incomplete. Still, they should fulfill a good purpose, I would think. Having said that, it will be important to read more than one book along with the course. The subsequent list provides some guidance in this respect. They are of a very different kind: While the book by Galindo/Pascual is mathematically much more pedantic and precise, for better or worse, the one by Schwabl is much more pragmatically minded.

0.2 Literature

The subsequent list is by no means comprehensive, and just gives a few hints where to look for. Specifically, the book by Galindo and Pascual is highly recommended.

Bibliography

[1] A. Galindo and P. Pascual, *Quantum mechanics II* (Springer, 1989).

[2] A. L. Fetter und J. D. Valecka, *Quantum theory of many-particle systems* (McGraw-Hill, 1971).

[3] E. K. U. Gross und E. Runge, *Vielteilchentheorie* (Teubner, 1986).

[4] W. Nolting, *Grundkurs theoretische Physik 7* (Springer, 2007).

[5] F. Schwabl, *Fortgeschrittene Quantenmechanik* (Springer, 2005).