Advanced Quantum Theory

Manfred Salmhofer, Institut für Theoretische Physik

Meisterklasse 2011

Lecture 1, April 15, 2011

Preliminaries

Coordinates

Module: MVAMO2, 2L+1T, 4 Credit Points

Lecture days and times:

Fridays, 9-11, großer Hörsaal, Philosophenweg 12

Tutorials: Tuesdays, every second week

Albert-Ueberle-Straße 3-5, Seminarraum I

INF 227, Seminarraum 1.404

please register for the tutorials

Additional lectures on certain Tuesdays: May 24, June 7, July 5

(saves some Fridays)

Credits and Examinations

Homework. Problem sets handed out before lectures;

due one week or ten days later.

Homeworks will be graded; admission to the exam if at least 50 % solved in a meaningful way.

Final: Takes place in exam week.

Contact

e-mail msalmhof@gmail.com

coming up soon:

http://www.thphys.uni-heidelberg.de/∼salmhof/AQT11/AQT11.html

Kambis Veschgini (K.Veschgini@thphys.uni-heidelberg.de)

organizes the tutorials

Contents

Modulhandbuch says

Module Contents (selection out of the following topics):

- Quantum theory of matter (Schrodinger equation, bosons and fermion, spin and statistics)
- Time-dependent quantum phenomena (scattering, atoms and molecules in external fields)
- Theory of quantum states (system and environment, pure and mixed states, density operator, entanglement, quantum information)
- Quantum theory of light and matter (quantized fields, interaction with atoms, quantum optics)
- Open quantum systems (matter and radiation, decoherence, non-equilibrium phenomena)
- Relativistic quantum theory (Dirac equation, relativistic light-matter interaction)

Objective: Understanding of fundamental concepts of quantum physics and the relevant theoretical methods

Prerequisites: not just PEP1-4, but also all standard Bachelors' theory courses, in particular Quantum Mechanics

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Carsten Müller offers a course "Fundamentale Wechselwirkungsprozesse zwischen Elektronen und Photonen"

Test

Ten questions about quantum mechanics

1. what is a quantum mechanical state
2. write down the time-dependent and the stationary Schrödinger equation, and explain the relation between the two
3. what is the interpretation of the wave function $\psi(t, x)$, and by which conservation law is it justified
4. why does $\psi(t, x)$ not simply define a mass density
5. what are quantum mechanical observables
6. what are the possible outcomes of experiments for an observable
7. what is the expected value and the variance of an obervable
8. under what condition are observables jointly measurable
9. what is the uncertainty relation and what does it mean
10. is time a quantum mechanical observable

Twenty questions about quantum mechanics

11. Is $-\frac{d^2}{dx^2}$ a positive or a negative operator on $\mathcal{S}(\mathbb{R})$?

12. Find the ground state of $H = \frac{1}{2}\left(-\frac{d^2}{dx^2} + x^2\right)$.

13. what is the spectrum of the H in 12. Why?

14. what is the Hamiltonian for the hydrogen atom

15. what is the spectrum of the hydrogen atom

16. why is there half-integer spin ?

17. how does spin-$\frac{1}{2}$ couple to a magnetic field

18. what is the dimension of the spin-ℓ representation of the angular momentum algebra

19. Find $\langle x \mid \mathrm{e}^{-\frac{\mathrm{i}}{\hbar}tH_0}x'\rangle$ for the free Hamiltonian $H_0 = \frac{P^2}{2m}$.

20. what is the Hamiltonian for a spin-0 particle in an electromagnetic field

Some more questions about quantum mechanics

21. What is the scattering amplitude

22. Write down the Lippmann-Schwinger equation

23. The variational principle states that . . .

24. The effect of a perturbation H' on the ground state energy is to first order . . .

25. The Feynman-Kac formula states that . . .

26. What is a mixed state

27. Von Neumann's equation reads . . .