Applied Quantum Mechanics: Advanced course

2B5317

Fall 2006

Aim

The aim of the course is to refresh the basic knowledge of quantum mechanics learned in undergraduate courses and to deepen this knowledge. The course will also present alternative views on quantum mechanics as well as advanced material. Toward the end of the course the students can choose between applications geared more towards solid state physics or geared towards quantum optics.

Examination

The course gives 5 academic credits and examination is by take-home problems.

Prerequisites

Familiarity with basic quantum mechanics as taught in undergraduate level courses is assumed.

Literature

Principles of Quantum Mechanics by R. Shankar (Solid state physics branch), *Introductory Quantum Optics* by C. C. Gerry and P. L. Knight (Quantum optics branch), complemented with supplementary material.

Don’t forget to order your book!

Schedule and location

10-12 tentatively according to the schedule below starting Thursday 10-12 September 7, 2006.

Lectures will be given in the OPQ conference room C3 in Electrum unless otherwise stated.

Lecturers

Gunnar Björk (GB), Anders Karlsson (AK), and Oscar Tjernberg (OT)

Content

30 hours divided into 15 lectures of two hours each.

1.	Overview of fundamentals	7/9	GB
	Kets, Bras and operators		
	Measurements, observables and commutation		
	The von Neumann postulate		
	Pauli's type one and type two measurements		
2.	Identical particles	14/9	OT
	Identical particles in quantum mechanics		
	Occupation number representation		
	Creation and annihilation operators		
	Fermions and Bosons		
	Operator representation		
3.	Electromagnetic field quantization	21/9	AK
	Harmonic oscillator		
	Number states		
	The coherent state		
	Coherence functions		
4.	Dynamics	3/10	OT
	Time evolution and Schrödinger equation		
	Schrödinger, Heisenberg and interaction picture		
	Modes and states		
5.	Optical components	5/10	GB
	Phase-shifter		
	Beam-splitter		
	Interferometer		
6.	Rotations and angular momentum	10/10	OT
	Rotations		
	Angular momenta		
	Cummutation relations		
	Eigenstates and eigenvalues		
	Addition of angular momenta		
7.	Symmetry in quantum mechanics	12/10	OT
	Translations and momenta		
	Groups		
	Permutation symmetry		
	Point groups		
	Energy bands		
or	Nonclassical light	19/10	GB
	Squeezed states		
	Photon antibunching		
	Schrödinger cat states		
8.	Optical test of quantum mechanics	26/10	AK
	Quantum interference		

Quantum nondemolition measurements
Quantum erasure measurements

9. Entanglement and nonlocality 2/11 GB
   The Einstein-Podolsky-Rosen “paradox”
   Bell’s inequality, the CHSH inequality
   Quantum teleportation

10. Perturbation theory 9/11 OT
    Time independent perturbation
    Degenerate and nondegenerate
    Time dependent perturbation

11. Atomic operators and interaction 16/11 GB
    Coherent states of atoms
    The Bloch sphere representation
    Interaction between light and matter

Lectures geared toward solid state physics/material physics:

12. Propagators and path integrals 27/11 OT
    Feynman paths
    Lagrangien and action
    Path integral
    Kernel

13. Propagators and path integrals cont. 29/12 OT
    Wavefunction and Schrödinger equation
    Kernel and Green’s function
    Semiclassical approximation

14. Many body methods 1/12 OT
    Green functions (again),
    Wick’s theorem and Feynman diagrams
    Dyson’s equation

15. The Anderson model 5/12 OT
    The Anderson and Kondo models
    Green functions for the Anderson model
    Spectroscopy and the Anderson model

Lectures geared toward quantum optics:

12. Entanglement II 23/11 AK
    Quantum key distribution
    Quantum computing

13. Cavity QED 30/11 AK
    The Jaynes-Cummings model
    Rabi oscillation

Mollow’s triplet
Creating entanglement

14. Entaglement quantification and classification 7/12 GB
Partitions, Schmidt decomposition
Entanglement of formation
Concurrence
Relative entropy
Distillable entanglement

15. Uncertainy, the Heisenberg limit 14/12 GB
The canonical uncertainty relation
Simultaneous uncertainty relation
Discrete uncertainty relation
Mutual unbiasedness
Other duality relations