



HÖGSKOLAN I KALMAR  
NATURVETENSKAPLIGA INSTITUTIONEN

**Kourse Fy3003 Artificiella atomer och kvantprickar, 7.5 högskolepoäng**

**VÅR 2009**

Artificial atoms and quantum dots, 7.5 ECTS credits

**Homepage:**

<http://www.kob.hik.se/fysik/coursepage.php?recordID=Artificiella%20atomer%20och%20kvantprickar>

\*\*\*\*\*

**Syllabus and time schedule**

**Legenda:**

**B&J\_PAM** stands for: B.H. Bransden and C.J. Joachain “*Physics of atoms and molecules*”

**B&J\_QM** stands for: B.H. Bransden and C.J. Joachain “*Quantum Mechanics*”

**Ch\_QD** stands for: T. Chakraborty, “*Quantum Dots*”

**Kou\_FEQD** stands for: L P Kouwenhoven et al., “*Few-electron quantum dots*”

**Ha\_spin** stands for: R. Hanson et al., “*Spin of Few-electron quantum dots*”

**Rei\_El** stands for: S. M. Reimann and M. Manninen, “*Electronic structure of quantum dots*”

**Week 4**

Tuesday, 20 January, 10.00-12.00

- Introduction and practicalities
- Interaction of one-electron atoms with electromagnetic radiation
  - The e.m. field and its interaction with charges (B&J\_PAM § 4.1)

Wednesday, 21 January, 10.00-12.00

- Interaction of one-electron atoms with electromagnetic radiation
  - Transition rates and the dipole approximation (B&J\_PAM § 4.2-4.3)

Thursday, 22 January, 10.00-12.00

- Interaction of one-electron atoms with electromagnetic radiation
  - The Einstein coefficients (B&J\_PAM § 4.4-4.5)

## Week 5

Tuesday, 27 January, 10.00-12.00

- Two electron atoms
  - Schrödinger equation for Helium atom. Spin wave functions (B&J\_PAM § 7.1-7.2)

Wednesday, 28 January, 10.00-12.00

Thursday, 29 January, 10:00-12.00

- Two electron atoms – cont'd
  - Level structure in the independent particle model (B&J\_PAM § 7.3-7.4)
  - Effect of Coulomb interaction (B&J\_PAM § 7.3-7.5)

## Week 6

Tuesday, 3 February, 10.00-12.00

- Many-electron atoms:
  - the central field approximation (B&J\_PAM § 8.1)

Wednesday, 4 February, 10.00-12.00

- exercises

Thursday, 5 February, 10.00-12.00

- Many-electron atoms:
  - The periodic system (B&J\_PAM § 8.2)
  - Hund's rules (B&J\_PAM § 8.5)

## Week 7

Tuesday, 10 February, 10.00-12.00

- Artificial atoms: quantum dots, nanoparticles, nanowires: overview (Kou\_FEQD, Rei\_EI)

Wednesday, 11 February, 10.00-12.00

- exercises

Thursday, 12 February, 10.00-12.00

- Theoretical models of quantum dots
  - 2D harmonic potential in magnetic field – the Darwin-Fock spectrum (Ch\_QD)
  - Constant interaction model (Kou\_FEQD)
  - Interaction effects beyond the CI model (Kou\_FEQD,

## Week 8

Tuesday, 17 February, 10.00-12.00

- Capacitance spectroscopy in quantum dots (Ch\_QD)
- Optical transitions (Ch\_QD)

Wednesday, 18 February, 10.00-12.00

Thursday, 19 February, 10.00-12.00

- Transport in quantum dots (Kou\_FEQD, Ch\_QD, Rei\_EI)
  - Coulomb Blockade

- Shell structure and magic numbers
- Diamond stability diagram

### Week 9

Tuesday, 24 February, 10.00-12.00

- spin in a few-electron quantum dots (Han\_spin)

Wednesday, 25 February, 10.00-12.00

- reserve

Thursday, 26 February, 10.00-12.00

- reserve

### Week 10

**5-6 March: take home exam**

### Week 12-13

**Presentation of project**

\*\*\*\*\*

#### Homework problems:

3-4 problem sets to be handed in. They will contribute ~40% of final grade

#### Class notes

My lecture notes will be available and put on the course homepage after every lecture.

### Literature

#### Compulsory

There is not one obligatory textbook. However I will try to specify the sections of the books (see reference bibliography) on which I will base my lectures.

Published review articles will also be used and distributed during the course.

#### Reference literature:

##### Books

1. T. Chakraborty, "*Quantum Dots: A Survey of the Properties of Artificial Atoms*", North-Holland, Amsterdam, 1999.
2. B.H. Bransden and C.J. Joachain "*Quantum Mechanics*"
3. B.H. Bransden and C.J. Joachain "*Physics of atoms and molecules*", Prentice Hall, UK (2003) ISBN 058235692X
4. C. Kittel, "*Introduction to Solid State Physics*", 8<sup>th</sup> edition, Wiley, 2004. ISBN 0-471-41526-X
5. H.P Myers, "*Introductory Solid State Physics*", 2<sup>nd</sup> Edition, Taylor & Francis, 1998, ISBN 0-7484-0659-X

### Review articles

1. M. Kastner, “*Artificial atoms*”, *Physics Today*, January 1993, 24 (1993).
2. R. C. Ashoori, “*Electrons in artificial atoms*”, *Nature*, **379**, 413 (1996).
3. L P Kouwenhoven, D G Austing and S Tarucha, “*Few-electron quantum dots*”, *Rep. Prog. Phys.* **64** (2001) 701–736.
4. S. M. Reimann and M. Manninen, “Electronic structure of quantum dots”, *Rev. Mod. Phys.* **74**, 1283, (2002).
5. R. Hanson, L P Kouwenhoven, J.R. Petta, S Tarucha, L.M.K. Vandersypen, “*Spin of Few-electron quantum dots*”, *Rev. Mod. Phys.* **79**, 1217, (2007).