UNIVERSITEIT TWENTE.

Name Module	Science
Language	English
Contact person	Dr ir J.M. Huijser, dr ir H. Wormeester (OLD AT)
Specific prerequisites (regarding incoming exchange)	Basic knowledge of Quantum mechanics and material structure (Builds upon knowledge acquired in M3 of AT / ST / TN)
Participating study	AT
Starting block	M9

Theme

This course gives a further introduction into modern physics and chemistry of (nano)matter. Starting from quantum physics and statistical physics the properties of atoms, molecules and solid state materials are derived. The module consists of 4 parts: Statistical Physics, Introduction to Solid State Physics, Molecules and Spectroscopy and Nanoscience.

Content (including project)

The content of the four parts is:

1. Statistical Physics The focus is on the relation between the atomic composition of a system (atoms in perpetual motion) and the ensuing macroscopic behavior (pressure, temperature, etc). Statistical descriptions are introduced to describe systems of 1E23 atoms in terms of partition functions, and their relations to thermodynamic potentials are discussed. The main topics include statistical definitions of entropy, internal energy and Helmholtz free energy, the Boltzmann distribution, Fermi-Dirac and Bose-Einstein distributions, the fundamental assumption of statistical mechanics, the equipartition theorem, equations of state. These concepts are applied to various simple systems, like ideal and non-ideal gases, solids and liquid mixtures.
2. Introduction to Solid State Physics: A crystalline material is described by its periodic lattice. The associated reciprocal space lattice is introduced and related to the characterization of a crystalline material with X-ray diffraction. The description of electron distribution in a material starts from the free electron model and with the aid of the reciprocal lattice the nearly free electron model is introduced. The concept of effective mass and Fermi-Dirac distribution are explained and several macroscopic features such as electron contribution to heat capacity and conductivity are treated. The influence of lattice dynamics on macroscopic properties is treated in terms of phonons and dispersion relations. Bose-Einstein distribution is used to evaluate the contribution of lattice dynamics to the heat capacity.
3. Molecules and Spectroscopy: This extend the knowledge introduced in the first year quantummechanics course and discusses the theory behind chemical bonding, as well as spectroscopic characterization. Topics being addressed involve the valence bond theory, hybridization of orbitals, molecular orbital theory, bonding and antibonding orbitals, electronic structures of molecules, introduction spectroscopy, vibrational transitions, rotational transitions and nuclear magnetic resonance.
4. Nanoscience: Introduction to Nanoelectronics (top-down vs bottom-up approach, relevant length scales). Free and confined electrons, tunnel junctions/resonant tunneling, single electron tunneling. Electronic structure of quantum dots, quantum wires and quantum wells and their transport properties. Coulomb blockade and single electron transistor.

Learning goals

Statistical Physics
- understands how the microscopic partition functions are determined by the atomic composition of a system;
- can derive partition functions for simple systems;
- can relate microscopic partition functions to macroscopic thermodynamic potentials;
- can apply these relations to simple systems;
- knows the crucial differences between classical (Boltzmann) and quantum mechanical (Fermi-Dirac, Bose-Einstein) systems.
- can interpret thermodynamic data in terms of microscopic behavior.

Introduction to Solid State Physics
- Identify the structure of a crystal lattice;
- Calculate a diffraction pattern and invert it back;
- Determine the electronic configuration of an atom;
- Compare the conductivity of a metal with the free electron model;
- Describe the behaviour of electrons in a periodic potential and explain the concept of a band structure;
- Calculate a 1D phonon dispersion relation;
- Determine the specific heat of a solid (Debye and Einstein models).

Molecules and spectroscopy
- Understand, explain and apply the physical principles of the Valence-bond theory and the Molecular orbital theory for chemical bonding;
- Understand and apply the hybridization of orbitals;
- Derive the electronic structure and bond order of homo- and heteronuclear diatomic molecules;
- Analyze the electronic structure from photoelectron spectroscopy data;
- Describe general features of molecular spectroscopy
  - Discriminate between the underlying photophysical processes of
  - Rotational, Vibrational and Electronic Spectroscopy
- Understand, explain and apply the physical principles of
  - Rotational Spectroscopy
  - Vibrational Spectroscopy
  - Electronic Spectroscopy

Nanoscience
- Can explain the difference between top-down vs bottom-up approach;
- Understand how relevant length scales influence the physical characteristics of nanodevices;
- Can apply the concepts of free and confined electrons in tunnel junctions/resonant tunneling, single electron tunneling;
- Can describe the electronicstructure of quantum dots, quantum wires and quantum wells and can relate this to the respective transport properties;
- Understands the concept of Coulomb blockade;
- Can explain the working of a single electron transistor;

Educational forms

Lectures, Tutorials, practicals

Assessments

Written tests, reports