

1. Advanced Solid State Physics

Oct 3, 2018

Advanced Solid State Physics

Solid state physics is the study of how atoms arrange themselves into solids and what properties these solids have.

Calculate the macroscopic properties from the microscopic structure.

Solid state physics

Every property of every solid can be calculated using multi-particle quantum mechanics.

$$H_{\text{mp}} = - \sum_i \frac{\hbar^2}{2m_e} \nabla_i^2 - \sum_a \frac{\hbar^2}{2m_a} \nabla_a^2 - \sum_{a,i} \frac{Z_a e^2}{4\pi\epsilon_0 |\vec{r}_i - \vec{r}_a|} + \sum_{i<j} \frac{e^2}{4\pi\epsilon_0 |\vec{r}_i - \vec{r}_j|} + \sum_{a<b} \frac{Z_a Z_b e^2}{4\pi\epsilon_0 |\vec{r}_a - \vec{r}_b|}$$



Introductory Solid State Physics

Crystals, Bravais lattices, Miller indices

Diffraction, Fourier transforms, Brillouin zones

Phonon dispersion and density of states

Free electrons dispersion and density of states

Calculation of thermodynamic properties from the DOS

Band structure calculations, empty lattice approximation,
tight binding, plane wave method

Bloch waves, translation operator

Advanced Solid State Physics

Review: Free electrons (noninteracting fermions), electrons in crystals

Review: Phonons (noninteracting bosons)

Semiconductors

Electrons in a magnetic field

Fermi surfaces

Quantum Hall effect

Magnetism

Linear response theory

Dielectric function / optical properties

Transport properties

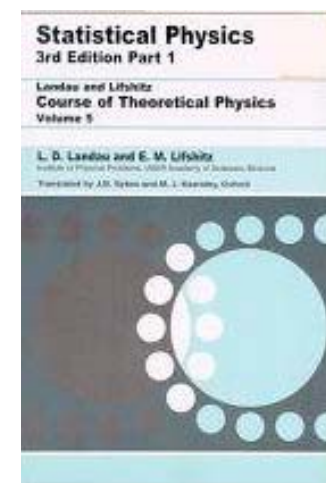
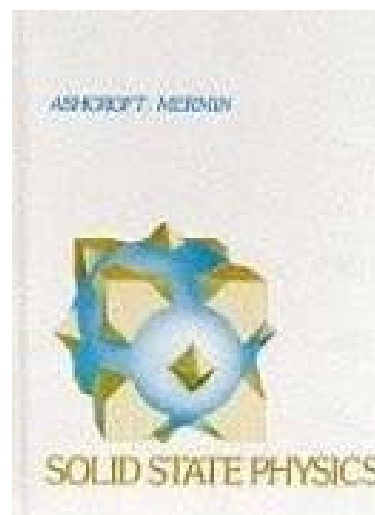
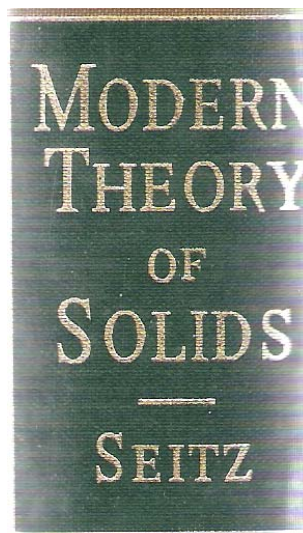
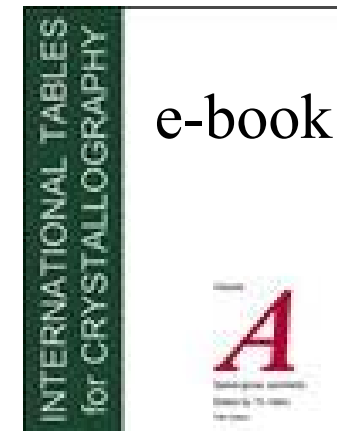
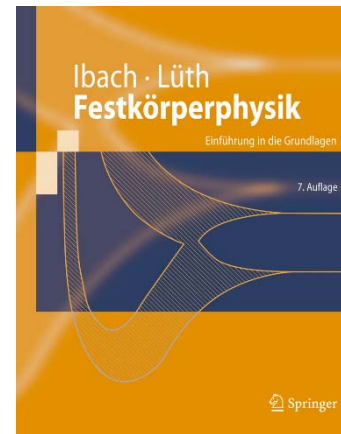
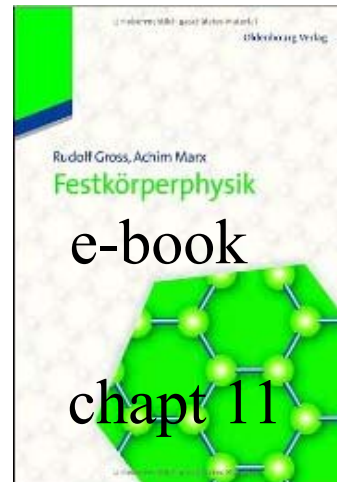
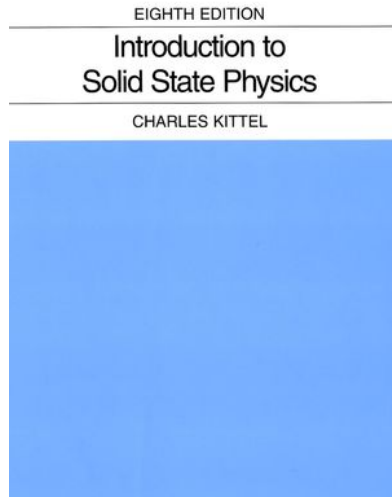
Ferroelectricity, pyroelectricity, piezoelectricity

Landau theory of phase transitions

Quasiparticles (phonons, magnons, plasmons, excitons, polaritons)

Mott transition, Fermi Liquid Theory

Superconductivity



Outline
Introduction
Quantization
Photons
Phonons
Electrons
Magnetic effects and Fermi surfaces
Crystal Physics
Linear response
Electron-electron interactions
Quasiparticles
Structural phase transitions
Landau theory of second order phase transitions
Transport
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Solid-state physics, the largest branch of condensed matter physics, is the study of rigid matter, or solids. The bulk of solid-state physics theory and research is focused on crystals, largely because the periodicity of atoms in a crystal, its defining characteristic, facilitates mathematical modeling, and also because crystalline materials often have electrical, magnetic, optical, or mechanical properties that can be exploited for engineering purposes. The framework of most solid-state physics theory is the Schrödinger (wave) formulation of non-relativistic quantum mechanics.

- [Solid state physics in Wikipedia](#)

The most remarkable thing is the great variety of *qualitatively different* solutions to Schrödinger's equation that can arise. We have insulators, semiconductors, metals, superconductors—all obeying different macroscopic laws: an electric field causes an electric dipole moment in an insulator, a steady current in a metal or semiconductor and a steadily accelerated current in a superconductor. Solids may be transparent or opaque, hard or soft, brittle or ductile, magnetic or non-magnetic.

From *Solid State Physics* by H. E. Hall

To a large extent, our success in understanding solids is a consequence of nature's kindness in organizing them for us... By the term solid we shall really always mean crystalline solid, and, moreover, infinite perfect crystalline solid at that.

From *States of Matter* by David L. Goodstein

<http://lampx.tugraz.at/~hadley/ss2/>

TUG -> Institute of Solid State Physics -> Courses

Student projects

Something that will help other students pass this course

2VO + 1UE

Derivation

Example calculations (phonon dispersion relation for GaAs)

Javascript calculations

Lecture videos

Examination

1 hour written exam

One page of handwritten notes

Oral exam

Student project

Mistakes on written exam

General questions about the course