《凝聚态物理》课程大纲

“Condensed Matter Physics” Course Outline

一、课程简介 (course description)

教学目标 (goal)：

Basic understandings of solids, energy bands, semiconductors, superconductivity and magnetism, and their main uses.

主要内容 (course contents)：

Condensed matter physics covers an extremely broad range of topics. Unfortunately therefore it is one of the most difficult course to teach and a one of the most boring course to learn. On the other hand, research in this area of physics has (arguably) resulted in the most useful outcomes. The topics to be covered in this course are crystal lattice structure, Bragg reflection and reciprocal lattice, phonons, free electron Fermi gas, energy band and band structure, semiconductors and semiconductor devices, Fermi surface and metals, superconductivities/magnetism, plasmon/plariton/polaron, optical properties and excitons, surfaces, interfaces, and nanostructures. We will try to make it fun by injecting more applied topics of relevance to our everyday lives such as semiconductor devices and applications.

二、教学内容 (teaching contents)

第一章 Chapter 1***

主要内容 Main subject：Crystal lattice structure

重点与难点 important and difficult points：Read Chapter 1 of the book. The materials are mostly definitions to be familiar with. Must remember 1 Å (angstrom) = 10^{-10} m (meter) = 0.1 nm (nanometer). The cases of simple, body-centered, and face-centered cubic lattice structures should be remembered. ***T*** (expressed in ***a***’s) defines a lattice.

第二章 Chapter 2***

主要内容 Main subject：Crystal diffraction and reciprocal lattice

重点与难点 important and difficult points：Review Fourier transform, light diffraction. Reciprocal lattice is essential in understanding X-ray Bragg reflections and therefore experimental determination of crystal structures. Structure factor and atomic form factor are introduced. ***G*** (expressed in ***b***’s which are in turn defined by ***a***’s) defines a reciprocal lattice.

第三章 Chapter 3***

主要内容 Main subject：Crystal binding

重点与难点 important and difficult points：difference and different binding strengths of various forces, van der Waals force treated in more mathematical terms with a physical model. Concepts of cohesive, lattice, and Madelung energies are introduced. Energy scales involved per atom are in the eV range.

第四章 Chapter 4***
主要内容 Main subject：Phonons: lattice vibration
重点与难点 important and difficult points：models of one-dimensional spring-connected harmonic oscillators give physical insight and realistic dispersion shapes, phonons are “quasi-particles” of lattice vibration, independent K values are within the first Brillouin zone

第五章 Chapter 5***
主要内容 Main subject：Phonons: thermal properties
重点与难点 important and difficult points：Density of state, Debye temperature, Debye and Einstein models, anharmonic effects, phonon-phonon scattering, thermal expansion, thermal conductivity/resistivity, Umklapp process

第六章 Chapter 6***
主要内容 Main subject：Free electron Fermi gas
重点与难点 important and difficult points：Electron motion is treated as though they are freely moving, Fermi-Dirac distribution, Fermi energy vs. chemical potential, Ohm’s law, Drude formula, Hall effect, specific heat, thermal conductivity

第七章 Chapter 7***
主要内容 Main subject：Energy band and band structure
重点与难点 important and difficult points：How does the periodic potential give rise to energy band?

第八章 Chapter 8***
主要内容 Main subject：Semiconductors and semiconductor devices
重点与难点 important and difficult points：Applications of band theory, band gap, and band structure, effective mass, hole.

第九章 Chapter 9***
主要内容 Main subject：Fermi surface and metal
重点与难点 important and difficult points：Everything happens at the Fermi surface, almost

第十章 Chapter 10***
主要内容 Main subject：Superconductivities and magnetism
重点与难点 important and difficult points: Basic concepts of superconductivity and magnetism, their physical mechanism.

第十一章 Chapter 11***
主要内容 Main subject：Plasmon/polariton/polaron, optical properties and excitons
重点与难点 important and difficult points：Various quasi-particles involving coupling among electrons, phonons, and photons.

第十二章 Chapter 12***
主要内容 Main subject：Surfaces, interfaces, and nanostructures

重点与难点 important and difficult points：Surfaces, interfaces and associated nanostructures form much of current research topics and promising applications.

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Lectures on Superconductivities and Magnetism will be given by Prof. Hang Zheng.
Some lectures on Energy Bands and/or Semiconductors will likely be given by Prof. Harald Schneider of Helmholtz Zentrum Dresden-Rossendorf, Germany, who is also a visiting chair professor with the SJTU.

三、教学进度安排 (detailed calendar)

Class locations & times: Tuesday & Thursday 10:00-11:40 东中院 1-104

	教学内容 Content	教学形式 Teaching format	作业 Homework
第一周 Week 1 (Feb. 14 & 16)	Introduction: solids, semiconductors, and their usefulness Crystal, lattice, diffraction, reciprocal lattice	Classroom lectures	Assignment 1: Read Ch. 1 What gadget would you like to have/invent and why? Due Feb. 21
第二周 (Feb. 21 & 23)	Wave diffraction, reciprocal lattice	Classroom lectures	Assignment 2: Reproduce Fig. 1 of Ch. 2, List formulas that you used. Problem #**1**, **4** & **6** of Ch. 2. Due March 1
第三周 (Feb. 28 & March 1)	Crystal binding	Classroom lectures	
第四周 (March 6 & 8)	Phonons I: Crystal vibrations	Classroom lectures	Assignment 3: 1. At the zone boundaries *K*=+/-p/*a*, how do the two modes look like? That is, what are relative values of *u* and *v*? Draw a picture (similar to Fig. 9) for these two modes for transverse modes. 2. Problem #1 of Ch. 4. *Due March 15.*
第五周 (March	Phonons II: Thermal	Classroom	Assignment 3:

13 & 15)	properties	lectures	Derive an expression for 2 dimension (let *A* be the area of the sample) Problem 5 in the book *Due March 22.*
第六周 (March 20 & 22)	Free electron Fermi gas	Classroom lectures.	Assignment 4: Reproduce Fig. 3. Derive DOS for 1 & 2D. *Due: March 29*
第七周 (March 27 & 29)	Free electron Fermi gas, Plasmons, polaritons, and polarons	Classroom lectures	
第八周 (April 3 ~~& 5~~)	Plasmons, polaritons, and polarons	Classroom lecture	
第九周 (April **10** & 12)	Energy bands	Classroom lectures, given by Prof. Schneider, & mid-term exam on April **10** at 2pm-3:40pm, 中院105(7-8节)	
第十周 (April 17 & 19)	Energy bands, and Semiconductors	Classroom lectures.	
第十一周 (April 24 & 26)	Semiconductors	Classroom lectures	
第十二周 (May 3)	Semiconductor devices	Classroom lecture, May 1 is a holiday	
第十三周 (May 8 & 10)	Superconductivities and magnetism	Classroom lectures – Prof. Zheng	
第十四周 (May 15 & 17)	Superconductivities and magnetism	Classroom lectures – Prof. Zheng	
第十五周 (May 22 & 24)	Superconductivities and magnetism	Classroom lectures – Prof. Zheng	
第十六周 (May 29 & 31)	Fermi surfaces and metals, Optical processes and	Classroom lectures	

	excitons, and Nanostructures		

（16 weeks total lecture time, weeks 17 & 18 – reading/final exam week）

Office hours: Every Tuesday after class **2:00pm-5:45pm**. On those no-class days, there will be no office hour. The office hour will be at my office (Physics Building, Room 902). During the period of Prof. Zheng’s lectures, the office hour will be held in Room 1011.

四、课程考核及说明 (Exams and grades)

40%为平时成绩（大作业等）Homework assignments

60%为考试成绩 Exams (mid-term 20% & final 40%)

五、教材与参考书 (books and references)

- Lecture notes, to provide softcopy
- Charles Kittle, "Introduction to Solid State Physics" (John Wiley & Sons, Inc, New York), 8th edition. Students are encouraged to get both the translation version and the English version.