**City University of Hong Kong**
**Course Syllabus**

**offered by Department of Physics**
**with effect from Semester A 2022/23**

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## Part I Course Overview

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|---|---|
| **Course Title:** | **Advanced Solid State Physics** |
| **Course Code**: | **PHY6521** |
| **Course Duration:** | **One semester** |
| **Credit Units**: | **3** |
| **Level**: | **P6** |
| **Medium of Instruction:** | **English** |
| **Medium of Assessment:** | **English** |
| **Prerequisites**: *(Course Code and Title)* | **AP3251/PHY3251 Quantum Mechanics or equivalent** |
| **Precursors**: *(Course Code and Title)* | **AP3290/PHY3290 Thermodynamics or equivalent**<br>**AP3272/PHY3272 Introduction to Solid State Physics or equivalent** |
| **Equivalent Courses**: *(Course Code and Title)* | **Nil** |
| **Exclusive Courses**: *(Course Code and Title)* | **PHY8521 Advanced Solid State Physics** |

**Part II Course Details**

## 1. Abstract

This course aims to equip graduate students with advanced knowledge of solid state physics that are necessary to understand contemporary literature and conduct frontier research in condensed matter physics and materials science. The course will start with a review of basic structural and electronic properties of crystals, with an emphasis on the band theory of electrons in periodic potentials. Then, the course will move on to thermodynamic and transport properties of metals, including the temperature dependence of specific heat and conductance, and basic magneto-transport properties. In the last part, the course will cover select advanced topics, which may include magnetism, superconductivity, topological band theory, a brief introduction to topological orders, and Berry phase effects in transport properties of the materials.

## 2. Course Intended Learning Outcomes (CILOs)

*(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)*

| No. | CILOs | Weighting (if applicable) | Discovery-enriched curriculum related learning outcomes (please tick where appropriate) | | |
|---|---|---|---|---|---|
| | | | *A1* | *A2* | *A3* |
| 1 | Acquire the basic knowledge of crystallography and electronic structure in solids, and the knowledge of fundamental differences between metals and insulators | | ✔ | ✔ | |
| 2 | Able to derive the Bloch theorem, and apply it to study band structures of toy models; able to analyze basic thermodynamic and transport properties of metals | | ✔ | ✔ | ✔ |
| 3 | Able to compute the Berry phase and topological properties of insulators in certain toy models | | ✔ | ✔ | ✔ |
| 4 | Acquire the basic knowledge of quantum Hall effects, edge states, topological insulators, Berry phase effect in metals | | ✔ | ✔ | |
| | | 100% | | | |

*A1: Attitude*
*Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.*

*A2: Ability*
*Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to self-life problems.*

A3: *Accomplishments*
*Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.*

## 3. Teaching and Learning Activities (TLAs)

*(TLAs designed to facilitate students' achievement of the CILOs.)*

| TLA | Brief Description | CILO No. | | | | Hours/week (if applicable) |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | |
| Lecture | Explain key concepts and formulate fundamental theories of selected topics in solid state physics | ✔ | ✔ | ✔ | ✔ | 2 hrs/wk |
| Tutorial | Solve some problems with certain techniques and discuss examples of the physical concepts and phenomena discussed in the lectures | ✔ | ✔ | ✔ | ✔ | 1 hrs/wk |

## 4. Assessment Tasks/Activities (ATs)

*(ATs are designed to assess how well the students achieve the CILOs.)*

| Assessment Tasks/Activities | CILO No. | | | | Weighting | Remarks |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | |
| Continuous Assessment: 40 % | | | | | | |
| Homework, Quizzes, etc | ✔ | ✔ | ✔ | ✔ | 40% | |
| Examination^: 60% (duration: 2 hrs) | ✔ | ✔ | ✔ | ✔ | 60% | |
| | | | | | 100% | |

^ For a student to pass the course, at least 20% of the maximum mark for the examination must be obtained.

## 5. Assessment Rubrics

*(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)*

Applicable to students admitted in Semester A 2022/23 and thereafter

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B) | Marginal (B-, C+, C) | Failure (F) |
|---|---|---|---|---|---|
| 1. Assignment | 1. Demonstrate correct understanding of key concepts.<br>2. Being able to use the taught knowledge and theory to solve problems | Will exhibit a high level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a good level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit some deficiencies in understanding, explaining, and integrating the knowledge in written format | Will exhibit lack of competence in understanding, explaining, and integrating the knowledge in written format |
| 2. Examination | 1. Demonstrate correct understanding of key concepts.<br>2. Being able to use the taught knowledge and theory to solve problems | Will exhibit a high level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a good level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit some deficiencies in understanding, explaining, and integrating the knowledge in written format | Will exhibit lack of competence in understanding, explaining, and integrating the knowledge in written format |

Applicable to students admitted before Semester A 2022/23

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B, B-) | Fair (C+, C, C-) | Marginal (D) | Failure (F) |
|---|---|---|---|---|---|---|
| 1. Assignment | 1. Demonstrate correct understanding of key concepts.<br>2. Being able to use the taught knowledge and theory to solve problems | Will exhibit a high level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a good level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a basic level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit some deficiencies in understanding, explaining, and integrating the knowledge in written format | Will exhibit lack of competence in understanding, explaining, and integrating the knowledge in written format |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| 2. Examination | 1. Demonstrate correct understanding of key concepts.<br>2. Being able to use the taught knowledge and theory to solve problems | Will exhibit a high level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a good level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit a basic level of competence in understanding, explaining, and integrating the knowledge in written format | Will exhibit some deficiencies in understanding, explaining, and integrating the knowledge in written format | Will exhibit lack of competence in understanding, explaining, and integrating the knowledge in written format |

**Part III Other Information** (more details can be provided separately in the teaching plan)

## 1. Keyword Syllabus

a. Review of crystal structure, band theory, tight-binding models, concept of metals and insulators.
b. Thermodynamic properties, specific heat.
c. Transport properties of metals and the Fermi Liquid Theory.
d. Measuring Fermi surfaces, quantum oscillations.
e. Band insulators, Berry phases, topological band theory.
f. Introduction to Superconductivity.
g. Quantum Magnetism.

## 2. Reading List

### 2.1 Compulsory Readings

*(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)*

N. W. Ashcroft and N. D. Mermin, **Solid State Physics** (Thomson Press, 2003)

### 2.2 Additional Readings

*(Additional references for students to learn to expand their knowledge about the subject.)*

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|---|---|
| 1. | M. Tinkham, **Introduction to Superconductivity** (New York: McGraw-Hill, 2nd ed., 1996) |
| 2. | S. H. Simon, **Solid State Basics** (Oxford University Press, Oxford, 2013) |
| 3. | C. Kittel, **Introduction to Solid State Physics** (Wiley, 8th ed, 2004) |
| 4. | P. Phillips, **Advanced Solid State Physics** (CRC press, 2002) |
| 5. | B. Andrei Bernevig, **Topological Insulators and Topological Superconductors** (Princeton University Press 2013) |
| 6. | A. Auerbach, **Interacting Electrons and Quantum Magnetism** (Springer New York 1994) |