**Centre for High Energy Physics**
**Faculty of Science**
**University of the Punjab, Lahore**

# Course Outline

| **Program** | BSCP | **Course Code** | CPHY 445 | **Credit Hours** | 3 |
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| **Course Title** | **Solid State Physics** |
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## Course Introduction

Solid State Physics is a major branch of Condensed Matter Physics and provides a theoretical basis to Material science. The course will provide a valuable introduction to Solid State Physics and an overview of crystal structure. The course not only will equip the students with the theoretical knowledge of crystal structure determination methods, but students will also learn X-ray diffraction, Neutron Diffraction, and Electron Diffraction experimental techniques as well. In addition, students will also get comprehensive knowledge about atomic bonding and the elastic behavior of the crystal lattice.

## Learning Outcomes

With the completion of the course, students will be able to:

1. Understanding the basic theme of Solid State Physics
2. Theoretical knowledge of the Crystal Structure
3. Learning the Experimental techniques to determine the crystal structure
4. Knowledge of atomic bonding in Solids and elastic behavior of crystal lattices

## Course Content

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| **Week 1** | Introduction to Condensed Matter Physics/Solid State Physics and its relation with materials Science. Why do we study Solid State Physics?Relationship of Solid State Physics to Other Areas |
| **Week 2** | • Crystal Structure: Periodic arrays of atoms<br>• Fundamental types of lattices<br>• Index system for crystal planes<br>• Simple crystal structures |
| **Week 3** | Direct imaging of atomic structure;Non-ideal crystal structure; Random Stacking and Polytypism |
| **Week 4** | • Reciprocal Lattice: Diffraction of waves by crystals<br>• Scattered wave amplitude; Brillouin zones<br>• Fourier analysis of the basis |
| **Week 5** | • Crystal Binding and Elastic Constants:Crystal of Inert Gases<br>• Ionic Crystals; Covalent crystals; Metals; Hydrogen Bonds |
| **Week 6** | • Atomic Radii; Analysis of elastic strains<br>• Elastic compliance and stiffness constants; Elastic waves in cubic crystal |
| **Week 7** | • Crystal Vibrations: Vibrations of crystals with a monatomic basis<br>• Two atoms per primitive basis; Quantization of elastic waves |

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| **Week 8** | • Phonon momentum; Inelastic scattering by phonons<br>• Thermal Properties: Phonon heat capacity (Plank Distribution, Normal Mode Numeration, Density of States in one dimension) |
| **Week 9** | • Density of States in three dimensions; Debye Model for Density of states; Einstein Model of the Density of states<br>• Inharmonic crystal interactions; Thermal conductivity; electronic heat capacity |
| **Week 10** | • Free Electron Theory: Energy levels in 1D; Effect of Temperature on the Fermi-Dirac distribution<br>• Free electron Gas in 3D; Heat capacity of the electron gas |
| **Week 11** | • Electrical conductivity and Ohm's law; Motion in a magnetic field<br>• Hall Effect; Thermal conductivity of metals |
| **Week 12** | • Band Theory: Nearly free electron model<br>• Bloch function; Kronig-Penney model |
| **Week 13** | • Wave equation of electron in a periodic potential<br>• Number of orbital in a band: Metals and Insulators |
| **Week 14** | • Semiconductor: Theory of semiconductors; Extrinsic semiconductors<br>• Mobility of current carriers; Minority carriers; Lifetime; Surfaces; Contacts;<br>• Semiconductor devices. |
| **Week 15** | Computational Techniques: Hartee-Fock Methods |
| **Week 16** | Density Functional Theory and LAPW method |

**Textbooks and Reading Material**

1. Introduction to Solid State Physics ($7^{th}$Edition), C. Kittle, *John Wiley & Sons, Inc.* (1996).
2. Solid State Physics, J. S. Blakemore, *Cambridge University Press* (1991).
3. Solid State Physics Simulations, Steven Spicklemire, *John Wiley & Sons* (1996).
4. Solid State Physics, Neil W. Ashcroft, *Thomson Press (India)*, 2003).
5. Solid State Physics ($2^{nd}$Edition), G. Grosso, G. P. Parravicini, Academic Press (2013).

**Teaching Learning Strategies**

The instructor is required to make use of visualization/animations and symbolic/numerical calculations to teach the concepts. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

**Assignments: Types and Number with Calendar**

At least two assignments and two quizzes. A course project may also be assigned.

| Sr. No. | Elements | Weightage | Details |
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| 1. | Midterm Assessment | 35% | Written Assessment at the mid-point of the semester. |

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| 2. | Formative Assessment | 25% | Continuous assessment includes Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc. |
| 3. | Final Assessment | 40% | Written Examination at the end of the semester. At least fifty percent of the question paper would involve new problems related to the concepts learned in the course.<br>It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc. |