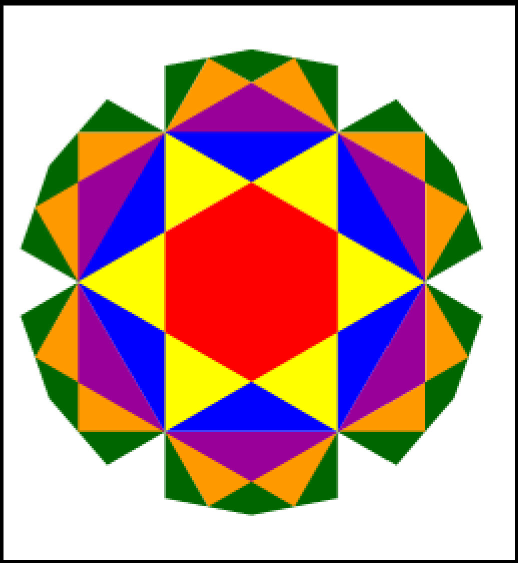
University of Glasgow | School of Physics & Astronomy



PHYS4028
Solid State Physics

Course Information Guide 2023-24

1 Course Details

PHYS4028 Solid State Physics is a level 4 Physics Honours course. It is compulsory for all students taking any of the Physics 4 degree options. It is composed of 18 lectures given in Semester 1.

Lecturer:

Dr. Donald MacLaren
Room 308b, Kelvin Building
Donald.MacLaren@glasgow.ac.uk

Time and place: Normally Mondays and Wednesdays 10:00 - 11:00 am.
See Moodle/ MyCampus for details of venue

Recommended Text: Charles Kittel, Introduction to Solid State Physics, (Wiley)
Electronic version available through the Library Reading List.

Course notes and Question Sheets will be made available on Moodle.

2 Assessment

The course will be assessed via an examination in the April/May diet. It provides 10 H-level credits.

3 Required Knowledge

A familiarity with the concepts of crystal structure including cubic unit cell types and Miller indexing of planes is essential. Students are also expected to have completed the Level 3 course PHYS4025 Quantum Mechanics. They should be familiar with the concept of a wave-function and apply the Schrödinger Equation for solution with running waves. Additionally we assume a familiarity with a mathematical description of diffraction and concepts of Fourier Transforms.

4 Intended Learning Outcomes

By the end of the course, students will be able to demonstrate a knowledge and broad understanding of Solid State Physics. They should:

- be familiar with the concept and application of the free electron theory; including periodic boundary conditions, enumeration of states in k-space, density of states and Fermi energy, all including thinking in 1D, 2D and 3D;

- understand the importance of the free electron theory in explaining electronic heat capacity, magnetic susceptibility, electron transport and heat capacity of metals;
- also be able to explain the limitations and failures of the free electron theory;
- demonstrate knowledge of different crystal systems and lattice and basis descriptions of crystals;
- understand the differences between x-ray, neutron and electron diffraction;
- understand the mathematical derivation for x-ray diffraction and the importance of atomic scattering and structure factors;
- demonstrate knowledge of the concept of the reciprocal lattice and how this relates to Bragg scattering;
- understand the importance of the Brillouin Zone in reciprocal lattice and its key role in diffraction;
- be able to describe the nearly free electron theory and explain qualitatively how this leads to energy bands;
- be able to understand how the central equations are formed in a periodic potential and how this leads to the concept of Bloch waves;
- understand the mathematical basis of energy gaps and then explain how these apply in 1D, 2D and 3D;
- know about the extended, periodic and reduced zone schemes in k-space and be able to draw and identify Brillouin Zones in 1D and 2D;
- understand how filling of states leads to metal, insulating and semiconducting behavior;
- be able to describe optical absorption for different semiconductors and explain the difference between direct and indirect gap materials;
- understand extrinsic semiconductors, the law of mass action and the concept of effective mass;
- be able to describe electron and hole concentrations in n and p type semiconductors and how the conductivity varies with temperature;
- understand the importance of the concept of crystal momentum and be able to describe the importance of holes, the mobility of charge carriers in semiconductors and the importance of the Hall effect; and
- be able discuss the limitations of the nearly free electron theory.

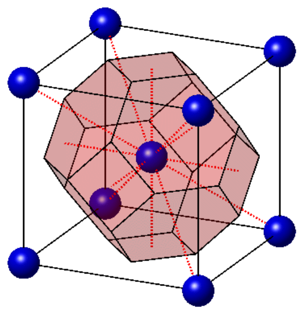


Fig. 1. The Wigner-Seitz cell for a simple body-centred cubic crystal.

5 Course Outline

5.1 Free electron theory

Free electron theory of metals

Assumptions. The electron sea. The Fermi surface. Calculation of Fermi parameters.

Electron heat capacity of metals.

Density of states. Heat capacity formulae. Decomposition from lattice heat capacity.

Free electron spin susceptibility

Pauli paramagnetism

Electron transport properties

Behaviour in an electric field. Scattering. Electrical conductivity. Motion in magnetic fields. Thermal conductivity of metals.

Successes and failures of free electron theory

5.2 Crystalline materials and diffraction

Crystalline materials (mainly revision)

Crystal lattice. Lattice planes. Crystal symmetry. Classification of lattice types. Cells in cubic crystals. Close packing.

Diffraction. How to determine crystal structures

Reflection from lattice planes. Radiation used in crystal diffraction – X-rays, neutrons, electrons. Full equation for diffraction from a lattice. Form factor, structure factor. Reciprocal lattice. Diffraction in reciprocal space. Brillouin zones. Conventional cells and systematic absences. Reciprocal lattices for cubic structures. Ewald sphere. Electron diffraction.

5.3 Nearly free electron model

Nearly free electron (NFE) model of materials

Qualitative description in 1-D, Bragg scattering leading to band structure, indication of how full solution for a periodic potential proceeds, Bloch theorem and Bloch functions, approximation for weak lattice potential, zone schemes, arbitrariness of k, enumeration of modes, towards 2-D and 3-D solutions, metals, semiconductors and insulators, construction of constant energy surfaces, electron and hole surfaces.

5.4 Semiconductors

General properties, crystal structures of common semiconductors, band structures, optical absorption, direct and indirect gap. Statistics of carriers of semiconductors at finite T, intrinsic and extrinsic behaviour, doping. Semiconductor transport in NFE model, electron equation of motion, crystal momentum, holes, effective mass, mobility. Hall effect.