UCLouvain

lmapr1492

2021

Materials physics

5.00 credits	37.5 h + 22.5 h	Q2

Teacher(s)	Charlier Jean-Christophe ;Gonze Xavier (coordinator) ;Piraux Luc ;Rignanese Gian-Marco ;
Language :	French
Place of the course	Louvain-la-Neuve
Prerequisites	LMAPR1491, LMAPR1805 *The prerequisite(s) for this Teaching Unit (Unité d'enseignement – UE) for the programmes/courses that offer this Teaching Unit are specified at the end of this sheet.*
Main themes	This course presents the basics of material physics (particularly periodic solids). The covered topics include: the basics of crystallography and diffraction, electronic band structures and its simple models, lattice vibrations and anharmonic effects, distinction between metals and semiconductors, basics of magnetism (particularly ferromagnetism), charge and heat transport phenomena.
Learning outcomes	**At the end of this learning unit, the student is able to :** 1 **Contribution of the course to the program objectives** • 1.1 ; • 2.3, 2.6, 2.7 **Specific learning outcomes of the course** 1. Describe the symmetry properties of crystalline solids; 2. Use the Born-Oppenheimer approximation to separate the electron and nuclei dynamics; 3. Compare different approximations (free, nearly-free, and tightly bound electron) regarding the electron behavior in crystalline solids and derive the concept of electronic band structure starting from Bloch's theorem; 4. Compute the vibrational modes for simple systems (atomic chains), and derive the dynamics of nuclei in crystalline solids using the harmonic, introduce the concept of phonon, and discuss anharmonic effects; 5. Compare the electronic properties of metals and semi-conductors and explain the effect of doping in the latter with an introduction to semiconductor devices; 6. Discuss des effects of external fields (electric et magnetic) on the electronic properties; 7. Explain electrical and thermal transport phenomena in crystalline solids; 8. Understand the magnetic properties of materials useful for engineers.
Evaluation methods	The students individually undergo a written evaluation (homework and written examination) on the basis of the above-mentioned learning outcomes. The final mark is obtained as the weighted sum of the results obtained for the "project" part (homework and correction) which amounts to 1/3 of the total, and for the written examination for which amounts to 2/3 of the total.
Teaching methods	Exercice sessions are proposed in parallel to the ex-cathedra lectures, allowing the student to apply the theoretical concepts presented during the lectures, and to allow them to develop associated competences. A written homework is also requested to the students as well as the correction of the homework of other students.
Content	1. Geometrical crystallography (point lattice; lattice systems ; lattice symmetry ; point symmetry ; space symmetry ; lattice plane ; reciprocal lattice ; Brillouin zone) 2. Structural crystallography (binding strength ; rare-gas crystals ; ionic crystals ; covalent crystals ; metallic crystals ; hydrogen-bonded crystals) 3. Basics of X-ray crystallography 4. Born-Oppenheimer approximation and independent electron approximation (splitting of the dynamics of nuclei and electrons, screening, exchange and correlation effects) 5. Periodic potential and band structure. (review of crystallography and symmetry, reciprocal space, Brillouin zone, Bloch theorem, density of states, Fermi surface, metals, insulators) 6. Nearly-free electron approximation (Born-Von Karman method, folding of the free electron parabola in the first Brillouin zone, Bragg reflections, gap opening, sodium, magnesium, aluminum)

	7. Tight-binding approximation (monoatomic linear chain, s-p bonding in semiconductors and carbon compounds, d bonding in transition metals, ionic compounds) 8. Thermal properties of solids (harmonic approximation; normal modes of vibration ; monoatomic and diatomic chains ; acoustic and optic modes; transverse and longitudinal modes ; the concept of phonons; examples of phonon band structures for different solids ; lattice specific heat ; anharmonic effects ; thermal expansion ; lattice thermal conductivity) 9. Dynamics of electrons in the periodic solid (equations of motion ; electric and magnetic field effects ; effective mass ; currents in bands : electrons and holes) 10. The free electron gas (occupation of states ; Fermi energy ; influence of temperature ; electronic specific heat) 11. Semiconductors (band structure; computation of electron and hole densities ; doping and impurity levels ; semiconductor devices : p-n junction, LED, transistor) 12. Transport phenomena in metals (electric conductivity ; electron-phonon collisions ; Hall effect and magnetoresistance ; electronic thermal conductivity) 13. Magnetic properties (introduction and overview of magnetic properties ; paramagnetism of the free electron gas ; band model of ferromagnetism ; magnetic anisotropies ; hysteretic cycles) 14. Superconductivity (introduction : experimental characteristics and theoretical approaches)
Inline resources	Moodle UCL
Bibliography	Quelques livres sont disponibles à la BST.
Faculty or entity in charge	FYKI

Programmes containing this learning unit (UE)

Program title	Acronym	Credits	Prerequisite	Learning outcomes
Specialization track in applied Chemestry and Physics	FILFYKI	5		
Minor in Applied Chemistry and Physics	MINOFYKI	5		
Minor in Engineering Sciences : Applied Chemistry and Physics (only available for reenrolment)	MINFYKI	5		