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| Teacher(s)          | Abreu Araujo Flavio ;Charlier Jean-Christophe ;Hackens Benoît ;  |
| Language :          | English<br>> French-friendly   |
| Place of the course | Louvain-la-Neuve   |
| Main themes         | This lecture provides an overview of the main physical phenomena linked to electrical and thermal transport as well as thermoelectric effects in materials. It also gives an introduction to spintronics and introduces the key features of electrical transport in nanostructures and low-dimensional systems, including quantum phenomena. Finally, laboratories allow the students to become acquainted with the experimental setup used for the measurements of transport properties as a function of temperature and magnetic field.  |
| Learning outcomes   | <p><b>At the end of this learning unit, the student is able to :</b></p> <p><b>Contribution of the course to the program objectives</b></p> <ul style="list-style-type: none"> <li>• Axe N°1 : 1.1 et 1.3</li> <li>• Axe N°2 : 2.1 et 2.2</li> <li>• Axe N°3 : 3.2 et 3.3</li> <li>• Axe N°4 : 4.2 et 4.4</li> <li>• Axe N°5 : 5.3 et 5.4</li> </ul> <p><b>Specific learning outcomes of the course</b></p> <ul style="list-style-type: none"> <li>• to compare the different types of materials when considering their thermal and electrical properties;</li> <li>• to explain the physical mechanisms involved at the nanoscale for the electrical and thermal conductivity as well as the temperature and magnetic field dependences;</li> <li>• to identify the useful materials for thermoelectric conversion;</li> <li>• to describe the experimental set-up for electrical and thermal measurements;</li> <li>• to comprehend the theoretical foundations of spintronics and to identify the useful materials and their principal applications;</li> <li>• to identify the quantum phenomena responsible for the new transport properties observed in nanostructures and low-dimensional systems;</li> <li>• to relate the transport properties of carbon nanostructures with their geometrical and electronic structure;</li> <li>• to become acquainted with the experimental setup used for the synthesis, characterisation and measurements of transport properties as well as the analysis of the results.</li> </ul> |
| Evaluation methods  | <p>The students will be evaluated :</p> <ul style="list-style-type: none"> <li>• individually, through a written and/or an oral exam, on the basis of precise objectives defined and announced in advance;</li> <li>• by group, on the basis of the written report of the practical labs.</li> <li>• The repartition of points is as follows : Prof. L. Piraux part for 2/3 of the points (oral exam part for 1/3 of the points and laboratory report for 1/3 of the points), Prof. J. C. Charlier part (oral exam) for 1/3 of the points.</li> </ul>  |
| Teaching methods    | Lectures (30 hours) alternate with practical labs totaling 30 hours on chosen subjects by the students. The practical labs enable to develop skills in various experimental methods (synthesis of nanostructures, use of characterization tools, design of an experimental set-up for electrical and thermal transport measurements, links between experimental results and theoretical knowledge). The class has about 8 weeks of practical labs for 2 hours each into groups of 3-4 students ; the remaining 6 weeks are mostly dedicated to tutoring sessions and guidance on the writing of the report.  |
| Content             | <p>1 : Bulk materials</p> <ul style="list-style-type: none"> <li>• Electrical conductivity : Theoretical expressions - Comparison between metals, semiconductors and semi-metals ' Scattering mechanisms and temperature dependence ' Link with band structure</li> <li>• Thermal conductivity : Theoretical expressions for lattice and electronic thermal conductivity ' Scattering mechanisms and temperature dependence - Comparison between different types of materials</li> <li>• Introduction to thermoelectricity : Seebeck et Peltier effects ' Influence of material - Thermoelectric conversion</li> <li>• Experimental aspects: Set-up for electrical and thermal measurements</li> <li>• Influence of magnetic field : Effect of a magnetic field quantum states of the electron gas and on the electron transport</li> </ul> <p>2 : Nanostructured materials and low-dimensional systems</p>  |

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|                             | <ul style="list-style-type: none"> <li>• Magnetic nanostructures : Introduction to spintronics, giant magnetoresistance in magnetic multilayers, tunneling magnetoresistance in magnetic tunnel junctions, prospects and concrete applications in spintronics</li> <li>• 2D systems: Examples of two-dimensional electron gas, density of states, influence of a magnetic field, quantum Hall effect, weak/strong localisation</li> <li>• 1D systems: Examples of one-dimensional electron gas, density of states, diffusive and ballistic transport, influence of a magnetic field, universal fluctuations of conductance, Coulomb blockade, quantization of conductance, Aharonov-Bohm effect</li> <li>• 0D systems: Examples of quantum dots, single-electron transistor, molecular transport</li> </ul> |
| Inline resources            | <a href="https://moodleucl.uclouvain.be/course/view.php?id=1_0023">https://moodleucl.uclouvain.be/course/view.php?id=1_0023</a>   |
| Bibliography                | Quelques livres sont disponibles à la BST.  |
| Other infos                 | For this lecture, it is assumed that the students have already acquired the basic concepts of materials sciences, quantum physics, statistical physics, and materials physics taught in bac 2 and in bac 3 (for example, in the lectures LMAPR1805, LMAPR1491, and LMAPR1492).  |
| Faculty or entity in charge | FYKI  |

| <b>Programmes containing this learning unit (UE)</b> |                         |         |              |   |
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| Program title  | Acronym                 | Credits | Prerequisite | Learning outcomes   |
| Master [120] in Chemical and Materials Engineering   | <a href="#">KIMA2M</a>  | 5       |              |  |
| Master [120] in Physical Engineering                 | <a href="#">FYAP2M</a>  | 5       |              |  |
| Advanced Master in Nanotechnologies                  | <a href="#">NANO2MC</a> | 5       |              |  |
| Master [120] in Energy Engineering                   | <a href="#">NRGY2M</a>  | 5       |              |  |