



## Subject card

Subject name and code	Transport properties of materials and superconductivity, PG_00038597						
Field of study	Nanotechnology						
Date of commencement of studies	October 2020	Academic year of realisation of subject			2023/2024		
Education level	first-cycle studies	Subject group			Optional subject group Subject group related to scientific research in the field of study		
Mode of study	Full-time studies	Mode of delivery			at the university		
Year of study	4	Language of instruction			Polish		
Semester of study	7	ECTS credits			2.0		
Learning profile	general academic profile	Assessment form			assessment		
Conducting unit	Zakład Elektrochemii i Fizykochemii Powierzchni -> Instytut Nanotechnologii i Inżynierii Materiałowej -> Faculty of Applied Physics and Mathematics						
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. inż. Natalia Wójcik					
	Teachers	dr hab. inż. Natalia Wójcik dr inż. Michał Winiarski					
Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	0.0	0.0	30
	E-learning hours included: 0.0						
Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours		Self-study	SUM	
	Number of study hours	30	0.0		0.0	30	
Subject objectives	Understanding the mechanisms of charge, heat and mixed transport in materials.  Gaining the information on superconductivity, parameters of the superconducting state and related types of ordering.						
Learning outcomes	Course outcome	Subject outcome			Method of verification		
	K6_W07	Student is able to describe and explain the effects of transport and superconductivity.			[SW1] Assessment of factual knowledge		
	K6_U06	Student possesses the knowledge of transport properties in low dimensional materials and is able to use it to describe the effects mentioned above.			[SU1] Assessment of task fulfilment		

Subject contents	<ol style="list-style-type: none"> <li>1. Introduction to the course (1h)</li> <li>2. Reminder of basic concepts related to transport: charge and heat transport, carriers, Fermi level, Fermi surface, state density, metals, semiconductors, compensated semiconductors, effective mass, its dependence on band dispersion, mobility, dispersion, relaxation time, Matthiessen's rule - (2h)</li> <li>3. Boltzmann kinetic equation, conductivity as a tensor, conductivity and electrical resistance in metal and semiconductor, activation conductivity, Arrhenius plots, resistance measurement methods - (3h)</li> <li>4. Ion transport, diffusion, Fick's laws, Nernst-Einstein equations, relation between diffusion and mobility - (3h)</li> <li>5. Magneto-resistance, classical approach to magnetoresistance, electron orbit in a magnetic field, Onsager's rule, Kohler's rule, giant magnetoresistance, magnetoresistance measurement - (3h)</li> <li>6. Shubnikov de Haas and de Haas van Alpen quantum oscillations, Hall effect, anomalous (spin) Hall effect, quantum Hall effect, measurement and application of the Hall effect - (3h)</li> <li>7. Thermal conductivity, thermoelectric effects: Seebeck, Peltier, Thomson and thermo-magnetic effects: Righi-Leduc, Nernst-Ettigshausen, Maggie-Righi-Leduc - (2h)</li> <li>8. Electron-electron and electron-phonon interaction (polarone), Hubbard model, Mott insulator, Kondo effect, topological insulator - (2h)</li> <li>9. Superconductivity (9 h)</li> <li>10. Introduction - discovery history, milestones;</li> <li>11. Properties of superconducting state, derivation and interpretation of London equations, basic assumptions of BCS theory;</li> <li>12. Measurements of superconductors: electrical resistance, magnetic susceptibility, specific heat;</li> <li>13. Determination of the basic parameters of the superconducting state, application of superconductors.</li> <li>14. test (2h)</li> </ol>		
Prerequisites and co-requisites	Completed the course of crystallography		
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Final test (written), 1h	50.0%	100.0%
Recommended reading	Basic literature	<ol style="list-style-type: none"> <li>1. M. Tinkham, <i>Introduction to Superconductivity</i>, Dover, 1996.</li> <li>2. M. Cyrot and D. Pavuna, ; (<i>Introduction to Superconductivity</i>, World Scientific, 1995).</li> <li>3. Charles Kittel, <i>Introduction to solid state physics</i></li> </ol>	
	Supplementary literature	A. B. Pippard, <i>Magnetoresistance in Metals</i> , Cambridge University Press, 1989	
	eResources addresses	Adresy na platformie eNauczanie: Właściwości transportowe materiałów i nadprzewodnictwo - Moodle ID: 33933 <a href="https://enauczanie.pg.edu.pl/moodle/course/view.php?id=33933">https://enauczanie.pg.edu.pl/moodle/course/view.php?id=33933</a>	
Example issues/ example questions/ tasks being completed	<ol style="list-style-type: none"> <li>1) Explain the phenomenon of giant magnetoresistance and write in what materials it can occur.</li> <li>2) How does the four probe resistance measurement work?</li> </ol>		
Work placement	Not applicable		