GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Physical fundamentals of nanotechnology, PG_00058948		
Field of study	Nanotechnology		
Date of commencement of studies	October 2023	Academic year of realisation of subject	2025/2026
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study 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	3	Language of instruction	Polish
Semester of study	6	ECTS credits	5.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Solid State Physics -> Faculty of Applied Physics and Mathematics -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	prof. dr hab. inż. Barbara Kościelska	
	Teachers	prof. dr hab. inż. Barbara Kościelska	

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	15.0	45
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	45	5.0	75.0	125

Subject objectives

The aim of the course is to acquaint students with the physical fundamentals of nanotechnology

Learning outcomes

Course outcome	Subject outcome	Method of verification
K6_W07	Knowledge of the physical basis of nanotechnology.	[SW1] Assessment of factual knowledge
K6_U11	The ability to present in Polish in the field of physical basics of nanotechnology.	[SU1] Assessment of task fulfilment [SU5] Assessment of ability to present the results of task
K6_W06	Basic knowledge of the physics of materials and nanomaterials.	[SW1] Assessment of factual knowledge

Subject contents	**Lecture** 1. Introduction. 1.1. General concepts related to nanotechnology. 1.2. Bonding in elemental solids: covalent, metallic and van der Waals bonding. 1.3. Bonding in multielement crystals: ionic, mixed ionic-covalent and hydrogen bonding. 1.4. Crystalline structure of solids. 1.5. Band structure of solids: free electron, nearly free electron and tight binding model. 1.6. Density of states in 0D, 1D, 2D and 3D materials. 2. Quantum nature of nanoworld. 2.1. Particle-wave nature of light and matter and the Heisenberg uncertainty principles. 2.2. Schrödinger equation, quantum states and energies, tunneling effect, reflection and tunneling at a potential step. 2.3. The particle trapped in 1D, 2D and 3D. 2.4. Quantum-well laser. 3. Electronic transport properties. 3.1. Diffusive and ballistic electron flow. 3.2. Landauer theory of quantum transport. 3.3. Ballistic transport in nanorods and quantum point contact. 3.4. Coulomb blocade and single electron transistor. 3.5. Quantum Hall effect. 4. Thermal properties. 4.1. Phonons and phonon density of states. 4.2. Specific heat of solids: Einstein and Debye theory of specific heat. 4.5. Thermal conductivity.

	4.6. Thermoelectric figure of merit of superlattices and nanorods, superlattice micro-coolers. 5. Magnetic properties and spin transport. 5.1. Spin-orbit coupling. 5.2. Magnetism and magnetic behaviour in matrials: interaction between magnetic moments, dia-, para- and ferromagnetism. 5.3. Spin Hall effect. 5.4. Magnetic nanowires. 5.5. Giant magnetoresistance (GMR) and tunnel magnetoresistance (TMR). 5.6. Spin transistors. 6. Photonic materials. 6.1. Electromgnetism in mixed dielectric media. 6.2. 1D, 2D and 3D photonic crystals. 6.3. Photonic band gap. 6.4. Metamaterials. 7. Properties of carbon nanotubes and graphen. 8. Production methods and research methods for nanostructures. **Seminar** The topic of the seminar is consistent with the topic of the lecture. Hybrid solar cells (cells that utilize nanostructures). Core-shell nanostructures: fabrication, physical properties, and application examples. Luminescent properties of semiconductor nanoparticles. Nanolithography. Using STM microscopy to fabricate nanostructures. Metallic nanoparticles: properties and applications. Nanobiosensors. Nanostructured organic LEDs. Magnetic nanomaterials and their applications. Methods for studying nanostructure surfaces. Spectroscopic methods for studying nanostructures. Nanoalloys: fabrication, properties, and applications.
Prerequisites and co-requisites	Completed a course of experimental physics.
Assessment methods and criteria	see table below

Subject passing criteria	Passing threshold	Percentage of the final grade
Obtaining at least a satisfactory grade in the seminar and participating in seminars	90.0%	30.0%
Written exam	50.0%	50.0%
Attending lectures	90.0%	20.0%

Recommended reading	Basic literature	1. Nanotechnologie. Red. Nauk. R.W.Kelsall i in. PWN 2008. 2. The Physics and Chemistry of Materials. J.I.Gersten, F.W.Smith, Wiley 2001. 3. Introduction to nanotechnology. Ch.P.Poole Jr, F.J.Owens. Wiley 2003 4. S.M.Lindsay, Introduction to Nanoscience, Oxford University Press, 2010 The student searches for materials for the seminar independently.
	Supplementary literature	The Oxford Handbook of Nanoscience and Nanotechnology, Vol. I-III, Ed. A.V. Narlikar, Y.Y. Fu, Oxford University Press, 2010
	eResources addresses	
Example issues/ example questions/ tasks being completed	1. Types of chemical bonds in crystal. 2. Density of states? Discuss the density of states g (E) in the system 0D, 1D, 2D and 3D. 3. Band structure of the crystal: how energy bands are formed and how do they affect the properties of the crystal. 4. Effective mass. 5. An electron trapped in one, two and three-dimensions. 6. A particle in a potential well and the tunnel effect. 7. Discuss the principle of the laser quantum wells and quantum dots. 8. Define the surface tension and surface energy, and discuss their importance in nanostructured systems. 9. Discuss phenomenon capable of varying surface energy. 10. Discuss the electron heat capacity and thermal conductivity. 11. Discuss the specific heat network and thermal conductivity. 12. Thermoelectric cooling: 3D systems and nanosize systems. 13. Quantization of conductivity - Landauer theory. 14. Three-dimensional and two-dimensional electron gas in an external magnetic field. 15. Quantum Hall effect and the effect of Shubnikova - de Hass. 16. Discuss the phenomenon of Coulomb blockade and the formation of the so-called. "Coulomb diamonds". 17. Discuss the polarization of dielectrics. 18. Propagation of light in the crystal. Maxwell's equations 19. What are the photonic structures and how they can be prepared. 20. A photonic gap. 21. What is the spin-orbit coupling (both in the atom as in the 2D electron gas)? 22. Applications of magnetic nanowires. 23. Spin Hall effect. 24. Kondo effect. 25. The phenomenon of giant magnetoresistance and magnetic tunnel junction. Transistor spin and spin valve. 26. List and discuss the physical properties of graphene and nanotubes.	
Work placement	Not applicable	