GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

<table>
<tr><td>Subject name and code</td><td colspan="6">Introduction to quantum mechanics, PG_00036980</td></tr>
<tr><td>Field of study</td><td colspan="6">Nanotechnology</td></tr>
<tr><td>Date of commencement of studies</td><td colspan="2">October 2022</td><td colspan="2">Academic year of realisation of subject</td><td colspan="2">2022/2023</td></tr>
<tr><td>Education level</td><td colspan="2">second-cycle studies</td><td colspan="2">Subject group</td><td colspan="2">Optional subject group
Subject group related to scientific research in the field of study</td></tr>
<tr><td>Mode of study</td><td colspan="2">Full-time studies</td><td colspan="2">Mode of delivery</td><td colspan="2">at the university</td></tr>
<tr><td>Year of study</td><td colspan="2">1</td><td colspan="2">Language of instruction</td><td colspan="2">English</td></tr>
<tr><td>Semester of study</td><td colspan="2">1</td><td colspan="2">ECTS credits</td><td colspan="2">5.0</td></tr>
<tr><td>Learning profile</td><td colspan="2">general academic profile</td><td colspan="2">Assessment form</td><td colspan="2">exam</td></tr>
<tr><td>Conducting unit</td><td colspan="6">Department of Solid State Physics -> Faculty of Applied Physics and Mathematics</td></tr>
<tr><td rowspan="2">Name and surname of lecturer (lecturers)</td><td colspan="2">Subject supervisor</td><td colspan="4">dr inż. Szymon Winczewski</td></tr>
<tr><td colspan="2">Teachers</td><td colspan="4">dr inż. Szymon Winczewski</td></tr>
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<tr><td rowspan="3">Lesson types and methods of instruction</td><td>Lesson type</td><td>Lecture</td><td>Tutorial</td><td>Laboratory</td><td>Project</td><td>Seminar</td><td>SUM</td></tr>
<tr><td>Number of study hours</td><td>30.0</td><td>30.0</td><td>0.0</td><td>0.0</td><td>0.0</td><td>60</td></tr>
<tr><td colspan="7">E-learning hours included: 0.0</td></tr>
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<tr><td rowspan="2">Learning activity and number of study hours</td><td>Learning activity</td><td>Participation in didactic classes included in study plan</td><td>Participation in consultation hours</td><td>Self-study</td><td>SUM</td></tr>
<tr><td>Number of study hours</td><td>60</td><td>5.0</td><td>60.0</td><td>125</td></tr>
<tr><td>Subject objectives</td><td colspan="5">The aim of the course is to familiarize students with the basics of quantum mechanics, which is the basis for a theoretical description of phenomena occurring at the atomic level. The subject is also aimed at preparing students for further education in the field of theoretical description and modeling of nanometer scale systems (courses such as: Computer modelling and desing of materials, "Quantum simulations with particles", Theoretical basis of nanotechnology).</td></tr>
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Learning outcomes	Course outcome	Subject outcome	Method of verification
	K7_W03	The student is able to independently study the given literature. The student is able to find content about issues discussed during the lecture, in order to re-study them in depth.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
	K7_U06	The student is able to present clearly his own solution to the given problem during tutorial classes and consultations. By tracking and analyzing the course of another person's solution he is able to assess its correctness and indicate mistakes made.	[SU1] Assessment of task fulfilment [SU5] Assessment of ability to present the results of task [SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject
	K7_U07	The student knows which of the phenomena and processes taking place on the atomic scale require the use of the quantum-mechanical description.	[SU3] Assessment of ability to use knowledge gained from the subject [SU2] Assessment of ability to analyse information
	K7_W02	The student has knowledge of quantum mechanics, which is a branch of modern physics. The student is able to present the laws of quantum mechanics. The student knows how to use the mathematical formalism of quantum mechanics to solve exemplary problems.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects
	K7_W09	The students is familiar with the terminology and nomenclature of the quantum mechanics. The student is able to present the acquired knowledge during the final written exam in theory.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects [SW2] Assessment of knowledge contained in presentation

Subject contents	1) Introduction a) history of quantum mechanics (years 1900-1930), b) analogies and differences in classical and quantum description, c) areas of quantum mechanics applications, 2) Basic concepts in the probability theory (a quick review) a) discrete variables, continuous variables, b) probability, probability density function, c) mean (average) value, deviation, variance, standard deviation, 3) Basics of quantum mechanics a) time-dependent Schrödinger equation, b) wave function, c) statistical interpretation of wave function, d) normalization of wave function, e) position and momentum operators, f) Ehrenfest theorem for position and momentum operators, g) correspondence principle, h) the importance of measurement, i) collapse of wave function, j) uncertainty principle, 4) Method for solving time-dependent Schrödinger equation a) separation of variables, b) stationary states and their properties, c) general solution as a linear combination of the stationary states, d) initial condition, e) time-independent Schrödinger equation, 5) Infinite square well a) problem formulation, b) solution of time-independent Schrödinger equation, c) form of the solutions and their properties, 6) Harmonic oscillator a) problem formulation, b) the importance of the problem, c) algebraic method (ladder operators, commutator of two operators, commutation relations), d) form of the solutions and their properties, e) analytic method (dimensionless variables, power series method, Hermite polynomials), 7) Free particle a) problem formulation, b) plane waves, c) wave packet, d) phase velocity, group velocity, 8) Dirca delta function potential a) bounded states and scattering states, b) problem formulation, c) form of the solutions and their properties, d) transition and reflection, 9) Finite square well a) problem formulation, b) form of the solutions and their properties, c) transition and reflection, 10) Formalism of quantum mechanics a) Hilbert space, b) inner product, c) Schwarz inequality, d) observables, e) Hermitian operators, f) eigenvalue problem (equation), eigenfunctions (eigenvectors), eigenvalues, g) general uncertainty priciple (for two operators, A and B), h) Dirac notation,

	11) Hydrogen atom a) problem formulation, b) Schrödinger equation in spherical coordinates, c) separation of variables, angular equation and radial equation, d) solution of the angular equation, associated Legendre polynomials, spherical harmonics, e) solution of the radial equation, associated Laguerre polynomials, f) quantum numbers, shells, subshells, orbitals, 12) Angular momentum a) angular momentum operator, b) commutation relations, c) ladder operators for angular momentum, d) quantization of angular momentum,
Prerequisites and co-requisites	Knowledge of mathematics and physics at the level of the first two years of study, in particular, a good knowledge of the following branches of mathematics and physics: differential calculus, integral calculus, probability theory, classical mechanics, electrostatics and magnetism, basics of modern physics.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
two written tests in problem solving	50.0%	50.0%
written exam in theory	50.0%	50.0%

Recommended reading

Basic literature	David J. Griffiths, Introduction to quantum mechanics, 2nd edition, Pearson Prentice Hall, 2005.
Supplementary literature	Ramamurti Shankhar, Principles of quantum mechanics, Plenum Press, 2011.
eResources addresses	Podstawowe https://enauczanie.pg.edu.pl/moodle/course/view.php?id=23673 - Introduction to quantum mechanics - online course on the eNauczanie platform Adresy na platformie eNauczanie: Introduction to quantum mechanics 2022/2023 - Moodle ID: 23673 https://enauczanie.pg.edu.pl/moodle/course/view.php?id=23673

Example issues/ example questions/ tasks being completed

1. Discuss analogies and differences between classical and quantum mechanics.
2. What is the probability density function? What properties does it have?
3. Present the time-dependent Schrödinger equation.
4. Discuss the statistical interpretation of the wave function.
5. Formulate Heisenberg's uncertainty principle for position and momentum operators and discuss its consequences.
6. Discuss the procedure used for solving the time-dependent Schrödinger equation.
7. Present the time-independent Schrödinger equation.
8. Explain why the stationary states are so important in quantum mechanics.
9. Solve the time-independent Schrödinger equation for an infinite potential well that extends between points 0 and a.
10. Express the Hamiltonian of the quantum harmonic oscillator in terms of ladder operators.
11. Explain what is the wave packet? What is the significance of this concept in quantum mechanics?
12. What does tunnelling mean? What are the consequences of this phenomenon?
13. What is the physical meaning of transmission T and reflection R coefficients? How are they defined? How are they related?
14. Discuss the properties of operators used in quantum mechanics.
15. Discuss Dirac notation.
16. Explain what is eigenproblem, eigenvector and eigenvalue. Give examples of eigenproblems in quantum mechanics.
17. Starting with Schwarz inequality derive the generalized uncertainty principle.
18. What are orbitals? What are shells? What are subshells? How do these concepts are related to quantum numbers n, l and m?
19. Discuss quantization of angular momentum.
20. For the given wave function calculate the expectation values. Check if Heisenberg's uncertainty principle is satisfied.

Work placement	Not applicable