Politechnika Krakowska im. Tadeusza Kościuszki

Karta przedmiotu

obowiązuje studentów rozpoczynających studia w roku akademickim 2022/2023

Wydział Inżynierii Materiałowej i Fizyki

Kierunek studiów: Fizyka Techniczna w Języku Angielskim — Profil: Ogólnoakademicki

Forma sudiów: stacjonarne — Kod kierunku: FTja

Stopień studiów: II

Specjalności: Computer modelling (modelowanie komputerowe w języku angielskim)

1 Informacje o przedmiocie

Nazwa przedmiotu	Quantum mechanics
Nazwa przedmiotu w języku angielskim	Quantum Mechanics
Kod przedmiotu	WIMiF FTJA oIIS C1 22/23
Kategoria przedmiotu	Przedmioty kierunkowe
Liczba punktów ECTS	4.00
Semestry	1

2 Rodzaj zajęć, liczba godzin w planie studiów

Semestr	Wykład	Ćwiczenia	Laboratorium	Laboratorium komputerowe	Seminarium	Projekt
1	30	30	0	0	0	0

3 Cele przedmiotu

Cel 1 Course Goal 1. Provide students with an advanced theoretical knowledge of quantum description of matter at the microscopic level.

Cel 2 Course Goal 2. Provide students with practical knowledge of general methods in computer modelling of quantum systems.

Cel 3 Course Goal 3. Raise awarness of importance of quantum phenomena for understanding properties of materials used in engineering and modern technology.

4 Wymagania wstępne w zakresie wiedzy, umiejętności i innych kompetencji

1 Prerequisite Course 1. Algebra and Calculus at the undergraduate level.

2 Prerequisite Course 2. Fundamentals in classical and quantum physics at the undegraduate level.

3 Prerequisite Course 3. Rudimentary computer skills in any programming language.

5 Efekty kształcenia

EK1 Wiedza Learning Outcome 1 (Knowledge). Extensive and advanced knowledge of quantum mechanics of atoms, molecules and condensed matter.

EK2 Wiedza Learning Outcome 2 (Knowledge). Current and modern applications of quantum mechanics in engineering and computer modelling related to materials science.

EK3 Umiejętności Learning Outcome 3 (Skills). Ability to generate and evaluate scientific and engineering evidence and explanations within the scope of quantum mechanics.

EK4 Umiejętności Learning Outcome 4 (Skills). Ability to identify various issues in materials science and engineering which are related to principles of quantum mechanics.

EK5 Kompetencje społeczne Learning Outcome 5 (Social Competences). Ability to do research and development or team work in commercial environment, including but not limited to, when necessary, to help co-workers with technical issues related to quantum mechanics as well as indicate reliable sources of technical information.

6 Treści programowe

Ćwiczenia		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
C1	Classical physics and Newton Laws. Equation of motion, time evolution models - problem examples. Analytical and numerical solutions of ordinary differential equation systems. Maple (or other free symbolic computation packages) application and MATLAB (or equivalent Octave/Python) codes.	6
C2	Mathematical solutions to simple problems from quantum physics. Discussing problems during tutorials. Working out solutions and practising a general attitute to find scientific explanations within framework of quantum mechanics. Validating and evaluating obtained solutions. Mid-term test 1. with use of e-learning platform ELF PK	10
C3	Computer modelling of some quantum problems with MATLAB. Matrix representation of the Hamiltonian operators. Time independent (eg. wavefunctions and eigenvalues for quantum harmonic oscillator) and time dependent problems (wavepacket scattering on a one-step barier). Visual representation of results (plots, animations). Visual representation of hydrogen wavefunctions.	10

Ćwiczenia		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
C4	Advanced mathematical formalism. Dirac notation, state vectors, operators. Discussion of some example problems and their solutions. Mid-term test 2. with use of e-learning platform ELF PK.	4

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W1	Introduction. Review of classical description of physical phenomena. Newton's Laws of motion. Conservation laws and symmetries. The Lagrangian method. The Hamiltonian formalism. The phase-space. The Poisson bracket. Hamilton's equations. Noether's theorem.	2
W2	Complex classical systems. Review of basics of equilibrium statistical physics. Stochastic processes. Time evolution versus probability distributions of statistical ensembles. Classical electromagnetism and special theory of relativity view on the light waves. Statistical description of light-matter interaction - the blackbody radiation. Planck's law and its ubiquity from smallest to the largest scales. Cosmic microwave background radiation. From physics of single quanta to the astrophysics of the Universe. Planck's constant as a fundamental constant for the new SI definition of the kilogram as a unit of mass.	4
W3	Limits on classical description of observed phenomena. Wave-particle duality. Matter waves. Modern experiments demonstrating non–classical (quantum) properties of materials and their properties. Electron microscopy.	2
W4	Mathematical formalism suitable for description of non-classical phenomena. Quantum wave matters and their superposition. Quantum interference. The wave packet and its properties. Wave packets and free particles. Uncertainty of wavepacket position. The Schroedinger equation for a free particle. Hilbert space and state vectors. Quantum operators in Hilbert spaces. Some mathematical theorems and their physical meaning.	2
W5	Formal postulates of quantum non-relativistic physics. Some remarks and discussion of the postulates. Fourier analysis for position and momentum operators (position and momentum space representations of these operators).	2
W6	Classical and quantum measurement. Statistical properties of observation from quantum postulates. The Heisenberg Uncertainty relations as a mathematical theorem. The proof of Heisenberg uncertainty theorem. Some remarks, examples and applications of Heisenberg uncertainty relations.	2
W7	Simple problems in one dimension. The free particle, the particle in a box, the continuity equation for probability. The single-step potential. The potential barier. Quantum tunneling. Scanning Tunneling Microscopy. Heterojunctions in semiconductorsa and other low-dimensional systems.	2

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W8	Ions in a trap with harmonic EM potential. Optical clocks as a new standard of time and frequency measurements. The quantum description of harmonic oscillator. Analytic and algebraic derivation of the solutions. Anihilation and creation operators. The canonical commutation rules and their applications. The classical limit of quantum oscillator.	4
W9	The density matrix approach. Systems with many particles and in many dimensions. Identical particles. Translation invariance in quantum theory. Time translatiional invariance. Parity invariance. Time-reversal symmetry.	2
W10	General algebra of quantum angular momentum operators. Addition of angular momenta. Spin and its nature.	4
W11	The Hydrogen atom. The Runge-Lenz operator and dynamical symmetry for the central interaction problem. Analytic Schroedinger and algebraic Pauli solution to eigenvalue problem for the Hydrogen atom. Rydberg atoms. Extreme atoms. Quantum chaos and Random Matrix Theory.	2
W12	The Helium atom. Approximate methods in quantum mechanics. The variational method. The Wentzel-Kramers-Brillouin method. Elements of scattering theory. The Dirac equation. More on relativistic quantum mechanics.	2

7 Narzędzia dydaktyczne

N1 Lectures, tutorials and in-class discussion

N2 Project

N3 Mid-term test

N4 Exam

N5 e-learning platform

8 Obciążenie pracą studenta

Forma aktywności	Średnia liczba godzin na zrealizowanie aktywności
Godziny kontaktowe z nauczycielem akademickim, w tym:	
Godziny wynikające z planu studiów	60
Konsultacje przedmiotowe	15
Egzaminy i zaliczenia w sesji	5
Godziny bez udziału nauczyciela akademickiego wynikające z nakładu pracy studenta, w tym:	
Przygotowanie się do zajęć, w tym studiowanie zalecanej literatury	20
Opracowanie wyników	0
Przygotowanie raportu, projektu, prezentacji, dyskusji	10
e-learning platform	10
Sumaryczna liczba godzin dla przedmiotu wynikająca z całego nakładu pracy studenta	**120**
Sumaryczna liczba punktów ECTS dla przedmiotu	4.00

9 Sposoby oceny

The total learning outcome is measured by a weighted average formed out of several assessment criteria for the (tutorials and the exam). The outcome index is expressed in per cents. The final grade from the Quantum Mechanics course will be assigned using a linear grading scheme. Control mid-term tests and the final exam will be carried out with the help of e-learning platform.

Ocena formująca

F1 Attendence

F2 Preparation for classes

F3 Performance/answers provided during classes

F4 Mid-term test

F5 Individual projects

F6 Exam

Ocena podsumowująca

P1 Total learning outcome index - weighted average out of partial scores

Warunki zaliczenia przedmiotu

W1 Tutorials pass grade (learning outcomes at the minimum level of 51%)

W2 Exam pass grade

W3 Performance meet the minimum criteria

Ocena aktywności bez udziału nauczyciela

B1 Using e-learning platform dedicated to our Quantum Mechanics course

B2 Optional individual projects on our dedicated e-learning platform

Kryteria oceny

Efekt kształcenia 1	
Na ocenę 2.0	Below 51% of the total learning outcome index
Na ocenę 3.0	In the range of 51 % - 60 % of the total outcome index. Knowledge meets the minimum criteria.
Na ocenę 3.5	In the range of 61 % - 70 % of the total outcome index.
Na ocenę 4.0	In the range of 71 % - 80 % of the total outcome index.
Na ocenę 4.5	In the range of 81 % - 90 % of the total outcome index.
Na ocenę 5.0	91 % or better of the total learning outcome
Efekt kształcenia 2	
Na ocenę 2.0	Below 51 % of the total learning outcome index.
Na ocenę 3.0	In the range of 51 % - 60 % of the total learning outcome index. Knowledge meets the minimum criteria
Na ocenę 3.5	In the range of 61 % - 70 % of the total learning outcome index.
Na ocenę 4.0	In the range of 71 % - 80 % of the total learning outcome index.
Na ocenę 4.5	In the range of 91 % - 90 % of the total learning outcome index.
Na ocenę 5.0	91 % or better of the total learning outcome index
Efekt kształcenia 3	
Na ocenę 2.0	Below 51 % of the total learning outcome index.
Na ocenę 3.0	In the range of 51 % - 60 % of the total learning outcome index. Skills meet the minimum criteria
Na ocenę 3.5	In the range of 61 % - 70 % of the total outcome index.
Na ocenę 4.0	In the range of 71 % - 80 % of the total outcome index.

Na ocenę 4.5	In the range of 81 % - 90 % of the total outcome index.
Na ocenę 5.0	91 % or better of the total learning outcome index
Efekt kształcenia 4	
Na ocenę 2.0	Below 51% of the total learning outcome index.
Na ocenę 3.0	In the range of 51 % - 60 % of the total learning outcome index. Skills meet the minimum criteria
Na ocenę 3.5	In the range of 61 % - 70 % of the total learning outcome index.
Na ocenę 4.0	In the range of 71 % - 80 % of the total learning outcome index.
Na ocenę 4.5	In the range of 81 % - 90 % of the total learning outcome index.
Na ocenę 5.0	91 % or better of the total learning outcome index.
Efekt kształcenia 5	
Na ocenę 2.0	Below 51 % the total learning outcome.
Na ocenę 3.0	In the range of 51 % - 60 % of the total learning outcome index.Social competences meet the minimum criteria
Na ocenę 3.5	In the range of 61 % - 70 % of the total outcome index.
Na ocenę 4.0	In the range of 71 % - 80 % of the total outcome index.
Na ocenę 4.5	In the range of 81 % - 90 % of the total outcome index.
Na ocenę 5.0	91 % or better of the total learning outcome

10 Macierz realizacji przedmiotu

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK1	K_W01b K_W02b K_W03	Cel 1 Cel 2 Cel 3	W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12	N1 N4 N5	F1 P1

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK2	K_W01b K_W02b K_W03	Cel 1 Cel 2 Cel 3	C2 C3 W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12	N1 N2 N4 N5	F3 F5 P1
EK3	K_U07b K_U09 K_U10b	Cel 2 Cel 3	C2 C3	N1 N2 N3 N4 N5	F1 F2 F3 F4 F5 P1
EK4	K_U13 K_U14 K_U15	Cel 1 Cel 2 Cel 3	C1 C2 C3 C4 W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12	N1 N2 N4 N5	F1 F2 F3 F5 P1
EK5	K_K01 K_K02 K_K03 K_K04	Cel 1 Cel 2 Cel 3	C1 C2 C3 C4 W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12	N1 N2 N3 N4 N5	F1 F2 F3 F4 F5 P1

11 Wykaz literatury

Literatura podstawowa

[1] R. Shankar — *Prinicples of Quantum Mechanics*, New York, 1994, Plenum Press

Literatura uzupełniająca

[1] A. Levi — *Applied Quantum Mechanics*, Cambridge, 2003, Cambridge University Press

Literatura dodatkowa

[1] G. Auletta, M. Fortunato and G. Parisi — *Quantum Mechanics*, Cambridge, 2009, Cambridge University Press

12 Informacje o nauczycielach akademickich

Osoba odpowiedzialna za kartę

dr Robert Gębarowski (kontakt: rgebarowski@pk.edu.pl)

Osoby prowadzące przedmiot

1 dr Robert Gębarowski (kontakt: rgebarowski@pk.edu.pl)

13 Zatwierdzenie karty przedmiotu do realizacji

(miejscowość, data) (odpowiedzialny za przedmiot) (dziekan)

Przyjmuję do realizacji (data i podpisy osób prowadzących przedmiot)

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