Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / SUBJECT SPECIFICATION	
Predmet:	Uvod v kvantno mehaniko
Subject Title:	Introduction to Quantum Mechanics

Študijski program Study programme	Študijska smer Study field	Letnik Year	Semester Semester
Fizika, 1. stopnja		3	5
Physics, 1st cycle		3	5

Vrsta predmeta / Course type Obvezni / compulsory

Univerzitetna koda predmeta / University subject code:

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Labor work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
40		20			120	**6**

Nosilec predmeta / Lecturer: doc. dr. Robert Hauko

Jeziki / Languages:	
Predavanja / Lectures:	slovensko/Slovenian
Vaje / Tutorial:	slovensko/Slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Priporočeno je predznanje iz moderne fizike in osnov algebre.

Vsaka izmed naštetih obveznosti v načinih ocenjevanja mora biti opravljena s pozitivno oceno. Opravljene sprotne naloge so pogoj za pristop k pisnemu izpitu.

Prerequisites:

Pre-knowledge of the Modern Physics and fundamentals of Algebra is recommended.

Each of the listed obligations in the assessment methods must be completed with a positive grade. Completed coursework is a prerequisite for taking the written exam.

Vsebina:

Content (Syllabus outline):

- Matematična orodja v kvantni mehaniki: Hilbertov prostor in valovne funkcije, Diracova notacija, operatorji, delta-funkcija, reprezentacija v diskretni in zvezni bazi, transformacija med bazami.
- Postulati v kvantni mehaniki: stanje sistema, verjetnostna gostota, princip superpozicije, opazljivke in operatorji, merjenja v KM, pričakovane vrednosti, princip nedoločenosti, časovni razvoj sistema, simetrije in ohranitveni zakoni.
- 1D primeri: potencialni skok, potencialna jama, harmonični oscilator, numerično reševanje Schroedingerjeve enačbe.
- Vrtilna količina: orbitalna, spinska, skupna.
- 3D primeri, vodikov atom.

- Mathematical methods in quantum mechanics: Hilbert space and wave functions, Dirac notation, operators, delta function, representation in discrete and continuous bases, change of bases.
- Postulates in quantum mechanics: state of the system, probability density, principle of superposition, observables and operators, measurements in QM, expectation values, uncertainty relations, time evolution of the system's state, symmetries and conservation laws.
- One-dimensional problems: potential step, potential well, harmonic oscillator, numerical solutions of the Schrödinger equation.
- Angular momentum: orbital angular momentum, spin, addition of angular momentum
- Three-dimensional problems, H-atom.

Temeljni literatura in viri / Textbooks:

1. N. Zettili, Quantum Mechanics – Concepts and Applications (Wiley, Chichester, 2005).
2. D. J. Griffits, Introduction to Quantum Mechanics (Prentice Hall, Upper Saddle River, 1994).
3. A. Ramšak, Kvantna mehanika (Založba Univerze v Ljubljani, Ljubljana, 2021).

Dodatna literatura / Additional readings:

1. M. C. Rogalski, S. B. Palmer, Quantum Physics (Gordon and Breach, Amsterdam, 1999).
2. Y. Peleg, R. Pnini, E. Zaarur, Schaum's outline of theory and problems of Quantum Mechanics (McGraw Hill, New York, 1998).

Cilji:

Študenti usvojijo temeljna matematična orodja kvantne mehanike, znajo opredeliti postulate, simetrije in ohranitvene zakone ter jih uporabiti za obravnavo nekaterih osnovnih ravnovesnih kvantnomehanskih sistemov.

Objectives:

Students obtain basic mathematical principles of Quantum Mechanics, are able to define postulates, symmetries and conservation laws and use them to tackle some basic equilibrium quantum-mechanical systems.

Predvideni študijski rezultati:

Intended learning outcomes:

Znanje in razumevanje: Po uspešno zaključeni učni enoti bodo študenti zmožni: - definirati kvantni sistem ter uporabiti matematične metode za njegov opis; - uporabiti napredna matematična orodja za izračun pričakovanih vrednosti različnih opazljivk v kvantomehanskem sistemu; - napovedati časovni razvoj sistema za sisteme, kjer se energija s časom ne spreminja; - izračunati energijska stanja v nekaterih analitično rešljivih enodimenzionalnih sistemih in za vodikov atom z reševanjem Schrödingerjeve enačbe in z matrično formulacijo; - obravnavati lastna stanja tirne, spinske in polne vrtilne količine ter prehode med stanji z različno projekcijo vrtilne količine. Prenesljive/ključne spretnosti in drugi atributi: Po uspešno zaključeni učni enoti bodo študenti zmožni: - uporabljati diferencialne enačbe drugega reda; - osnove nekomutativne algebre uporabiti za reševanje fizikalnih problemov; - uporabljati unitarno in Fourierovo transformacijo; - v optiki uporabiti matematično analogijo pri obravnavi tanke plasti (potencialna plast v KM), odboj in lom (potencialni skok) itd… - brati strokovne tekste s področja moderne fizike (Diracova notacija, Hilbertov prostor, operatorji, pričakovane vrednosti…) ;	Knowledge and Understanding: On completion of this course students will be able to: - define a quantum system and use mathematical methods for its description; - use advanced mathematical tools to find expectation values of different observables in a quantum-mechanical system; - predict the time development of systems in which energy does not change with time; - calculate energy levels in some analytically solvable one-dimensional systems and for a hydrogen atom by using the Schrödinger equation and matrix formulation; - find the eigen states of the orbit, spin and total angular momentum and discuss transitions between states with different projection of angular momentum. Transferable/Key Skills and other attributes: On completion of this course students will be able to: - use second order differential equations; - apply methods of noncommutative algebra to solve physical problems; - use unitary and Fourier transformations; - use mathematical analogies in optics to study thin films (potential barrier in QM), reflection and refraction (potential jump), etc. - read scientific literature in the field of modern physics (Dirac notation, Hilbert space, operators, expected values…)
Metode poučevanja in učenja:	**Learning and teaching methods:**

predavanja teoretične vaje razlaga razgovor demonstracija delo s tekstom metoda pisnih in grafičnih del uporaba simulacij uporaba simulacijskih okolij	lectures theoretical excercises explanation discussion demonstration work with text work with graphic elements use of simulations use of simulation software

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
pisni izpit sprotne naloge	50% 50%	written exam coursework

Opombe:
Pisni izpit se lahko nadomesti s štirimi pisnimi kolokviji.

Comments:
Written exam can be replaced by four written midterm examinations.

Reference nosilca / Lecturer's references:

1. HAUKO, Robert, PADEŽNIK GOMILŠEK, Jana, KODRE, Alojz, ARČON, Iztok, LUIN, Uroš. Iodine K- and L-edge X-ray absorption spectra of HI : the effect of molecular orbitals and core subshells. *Radiation physics and chemistry*. [Print ed.]. 2025, vol. 229, [article no.] 112509, str. 1-8, ilustr. ISSN 0969-806X. DOI: 10.1016/j.radphyschem.2025.112509. [COBISS.SI-ID 221442051]

2. HAUKO, Robert, DAJNKO, Matic, GAČEVIĆ, Dino, MARINKO, Peter, POTRČ, Melani, REPNIK, Robert. From speed of sound to vapour pressure : an undergraduate school experiment as an example of systematic error research. *European journal of physics*. 2022, vol. 43, no. 4, str. 1-14. ISSN 0143-0807. DOI: 10.1088/1361-6404/ac6cb9. [COBISS.SI-ID 117802755]

3. HAUKO, Robert, PADEŽNIK GOMILŠEK, Jana, KODRE, Alojz, ARČON, Iztok. X-ray absorption spectroscopy set-up for unstable gases : a study of 5p hydrides. *Radiation physics and chemistry*. [Print ed.]. Jun. 2020, vol. 171, str. 1-4, ilustr. ISSN 0969-806X.
DOI: 10.1016/j.radphyschem.2020.108743. [COBISS.SI-ID 5564411]

4. HAUKO, Robert, PADEŽNIK GOMILŠEK, Jana, KODRE, Alojz, ARČON, Iztok, AQUILANTI, Giuliana. Effects of the molecular potential on coexcitations of valence electrons in the K-shell photoeffect of 3p and 4p elements. *Physical review. A*. 2019, vol. 99, no. 6, str. 062501-1-062501-10. ISSN 2469-9926. DOI: 10.1103/PhysRevA.99.062501. [COBISS.SI-ID 22395158].