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, level 1		3	5

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: prof. dr. Nataša Vaupotič

Jeziki / Languages:	**Predavanja / Lecture:**	slovensko/Slovenian
	Vaje / Tutorial:	slovensko/Slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Predznanje iz moderne fizike in osnov algebre.	Pre-knowledge of the Modern Physics and basic Algebra.

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 primer: 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. M. C. Rogalski, S. B. Palmer, Quantum Physics (Gordon and Breach, Amsterdam, 1999).
3. D. J. Griffits, Introduction to Quantum Mechanics (Prentice Hall, Upper Saddle River, 1994).
4. Y. Peleg, R. Pnini, E. Zaarur, Schaum's outlines – Quantum Mechanics (McGraw Hill, New York, 1998).
5. katerakoli knjiga, ki ima v naslovu Kvantna mehanika ali Uvod v kvantno mehaniko ali Osnove kvantne mehanike…

Cilji:	**Objectives:**
Študenti usvojijo temeljna matematična orodja kvantne mehanike, znajo opredeliti postulate, simetrije in ohranitvene zakone ter jih uporabiti za obravnavo nekaterih osnovnih ravnovesnih kvantnomehanskih sistemov.	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 • tutorsko delo	• lectures • theoretical excercises • tutorial work

• razlaga • razgovor • demonstracija • delo s tekstom • metoda pisnih in grafičnih del • uporaba simulacij • uporaba simulacijskih okolij	• 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 (lahko se nadomesti s pisnimi kolokviji)	50%	Written exam (can be replaced by written tests)
ustni izpit (zagovor teoretičnih nalog)	50%	Oral exam (defence of theoretical exercises)
Za uspešno zaključeno učno enoto mora vsak del posebej biti pozitiven; vse teoretične naloge morajo biti izračunane in zagovorjene.		For a successful completion, both written and oral exams must be positive; all theoretical problems must be solved and defended.

Reference nosilca / Lecturer's references:

1. SALAMONCZYK, Miroslaw, VAUPOTIČ, Nataša, POCIECHA, Damian, WALKER, Rebecca, STOREY, John M. D., IMRIE, Corrie T., WANG, Cheng, ZHU, Chenhui, GÓRECKA, Ewa. Multi-level chirality in liquid crystals formed by achiral molecules. *Nature communications*, ISSN 2041-1723, 2019, vol. 8, str. 1922-1-1922-8, doi: 10.1038/s41467-019-09862-y. [COBISS.SI-ID 32322855.

2. VAUPOTIČ, Nataša, ALI, Muhammad, MAJEWSKI, P., GÓRECKA, Ewa, POCIECHA, Damian. Polarization gratings spontaneously formed from a helical twist-bend nematic phase. *ChemPhysChem : a European journal of chemical physics and physical chemistry*, ISSN 1439-4235. [Print ed.], [in press] 2018, 15 str., doi: 10.1002/cphc.201800360. [COBISS.SI-ID 31667751].

3. POCIECHA, Damian, CRAWFORD, Catriona A., PATERSON, Daniel A., STOREY, John M. D., IMRIE, Corrie T., VAUPOTIČ, Nataša, GÓRECKA, Ewa. Critical behavior of the optical birefringence at the nematic to twist-bend nematic phase transition. *Physical review. E*, ISSN 2470-0045, 2018, vol. 98, no. 5, str. 052706-1-052706-5, doi: 10.1103/PhysRevE.98.052706. [COBISS.SI-ID 31948071].

4. SALAMONCZYK, Miroslaw, VAUPOTIČ, Nataša, POCIECHA, Damian, WANG, Cheng, ZHU, Chenhui, GÓRECKA, Ewa. Structure of nanoscale-pitch helical phases : blue phase and twist-bend nematic phase resolved by resonant soft X-ray scattering. *Soft matter*, ISSN 1744-683X, 2017, vol. 13, no. 38, str. 6694-6699, doi: 10.1039/c7sm00967d. [COBISS.SI-ID 30804519].

5. GÓRECKA, Ewa, VAUPOTIČ, Nataša, ZEP, Anna, POCIECHA, Damian. From sponges to nanotubes : a change of nanocrystal morphology for acute-angle bent-core molecules. *Angewandte Chemie*, ISSN 1521-3773. [Online ed.], 2016, vol. 55, no. 40, str. 12238-12242, doi: 10.1002/anie.201604915. [COBISS.SI-ID 29763367].

6. VAUPOTIČ, Nataša, CURK, Samo, OSIPOV, Mikhail, ČEPIČ, Mojca, TAKEZOE, Hideo, GÓRECKA, Ewa. Short-range smectic fluctuations and the flexoelectric model of modulated nematic liquid crystal. *Physical review. E, Statistical, nonlinear, and soft matter physics*, ISSN 1539-3755, 2016, vol. 93, no. 2, str. 022704-1-022704-5, doi: 10.1103/PhysRevE.93.022704. [COBISS.SI-ID 29301799].