



Univerza v Mariboru

Fakulteta za naravoslovje  
in matematiko

### UČNI NAČRT PREDMETA / COURSE SYLLABUS

|                      |  |
|----------------------|--|
| <b>Predmet:</b>      | Izbrana poglavja iz kvantne mehanike   |
| <b>Course title:</b> | Selected topics from Quantum Mechanics |

| Študijski program in stopnja<br>Study programme and level | Študijska smer<br>Study field | Letnik<br>Academic year | Semester<br>Semester |
|---|-------------------------------|-------------------------|----------------------|
| Fizika 2. st.   |                               | 1                       | 2                    |
| Physics 2 <sup>nd</sup> degree                            |                               | 1                       | 2                    |

**Vrsta predmeta / Course type**

**Univerzitetna koda predmeta / University course code:**

| Predavanja<br>Lectures | Seminar<br>Seminar | Vaje<br>Tutorial | Klinične vaje<br>work | Druge oblike<br>študija | Samost. delo<br>Individ.<br>work | ECTS |
|------------------------|--------------------|------------------|-----------------------|-------------------------|----------------------------------|------|
| 30                     | 0                  | 15               | 0                     | 0                       | 105                              | 5    |

**Nosilec predmeta / Lecturer:**

|                                |                                   |  |
|--------------------------------|-----------------------------------|--|
| <b>Jeziki /<br/>Languages:</b> | <b>Predavanja /<br/>Lectures:</b> | <input type="text" value="slovenski/Slovenian"/> |
|                                | <b>Vaje / Tutorial:</b>           | <input type="text" value="slovenski/Slovenian"/> |

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

Formalno ali neformalno znanje iz moderne fizike, osnov algebre in analize, uvoda v kvantno mehaniko.

**Prerequisites:**

Formal or informal knowledge of the Modern Physics, basic Algebra and Calculus, Introduction to Quantum Mechanics.

**Vsebina:**

**Content (Syllabus outline):**

Skalarni, vektorski in tenzorski operatorji.  
 Rotacije v kvantni mehaniki, vrtilna količina, seštevanje vrtilnih količin, sklopitev spin-tir.  
 Sistem več delcev: sistem ločljivih in neločljivih delcev, Paulijevo izključitveno načelo.  
 Približne metode za stacionarna stanja: časovno neodvisna teorija motenj, variacijska metoda.  
 Časovno odvisna teorija motenj: verjetnost za prehod v konstantnem in v periodičnem potencialu, adiabatska aproksimacija, interakcija atomov z EM valovanjem, izbirna pravila za električni dipolni prehod.  
 Teorija sipanja: sipalni presek, sipalna amplituda, Bornova aproksimacija.

Scalar, vector and tensor operators.  
 Rotations in quantum mechanics, angular momentum, addition of angular momenta, coupling of orbital and spin angular momenta.  
 Many-particle systems: systems of distinguishable and identical particles. Pauli exclusion principle.  
 Approximation methods for stationary states: time independent perturbation theory, the variational method.  
 Time dependent perturbation theory: transition probability for a constant and for a harmonic perturbation, adiabatic approximation, interaction of atoms with radiation, the electric dipole selection rules.  
 Scattering theory: scattering cross section, scattering amplitude, the Born approximation.

### Temeljni literatura in viri / Readings:

1. N. Zettili, Quantum Mechanics – Concepts and Applications (Wiley, Chichester, 2003).
2. M. C. Rogalski, S. B. Palmer, Quantum Physics (Gordon and Breach, Amsterdam, 1999).
3. D. J. Griffiths, 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).

### Cilji in kompetence:

Študenti nadgradijo osnovno znanje iz kvantne mehanike z vsebinami, ki so osnova za razumevanje in obravnavo pojavov v fiziki trde in mehke snovi ter v biofiziki. Usvojeno znanje in matematična orodja znajo uporabiti za obravnavo nekaterih osnovnih kvantnomehanskih procesov.

### Objectives and competences:

Students enrich the basic knowledge in quantum mechanics with topics, which are elemental for understanding and studying the phenomena in solid state physics, in soft matter physics and in biophysics. They can use the acquired knowledge and mathematical tools to tackle some basic quantum-mechanical processes.

### Predvideni študijski rezultati:

#### Znanje in razumevanje:

Po uspešno zaključeni učni enoti bodo študenti zmožni:

- seštevati vrtilne količine (posebni primer: sklopitev spin-tir)
- sestaviti valovno funkcijo sistema delcev s pravilno simetrijo (ločljivi, neločljivi delci, fermioni, bozoni)

### Intended learning outcomes:

#### Knowledge and understanding:

On completion of this course students will be able to:

- perform addition of angular momenta (special case: spin-orbit coupling)
- construct wavefunction with adequate symmetry for a system of particles (identical, distinguishable, fermions, bosons)

- uporabiti približne metode za izračun stacionarnih stanj: perturbativno, variacijsko in WKB (posebni primer: popravek fine strukture in Zeemanov učinek)
- izračunati verjetnosti za prehod pri konstantni in pri periodični motnji z uporabo časovno odvisne perturbacijske metode
- uporabiti adiabatski približek in približek nenadnega prehoda
- izračunati verjetnost prehoda v dipolnem približku interakcije atoma z elektromagnetnim valovanjem, uporabiti izbirna pravila
- izračunati sipalni presek v Bornovi aproksimaciji

**Prenesljive/ključne spretnosti in drugi atributi:**

Po uspešno zaključeni učni enoti bodo študenti zmožni:

- uporabljati usvojene matematične in fizikalne metode pri problemih s področij trdne in mehke snovi ter biofizike
- uporabljati računalniška orodja za analitično in za numerično računanje
- brati strokovne tekste s področja moderne fizike

- use approximation methods for computation of stationary states: perturbation, variational and WKB (special cases: fine structure, Zeeman effect)
- calculate transition probability for a constant and for a harmonic perturbation with time-dependent perturbation method
- use adiabatic and sudden approximations
- calculate transition rates within the dipole approximation for interaction of atoms with radiation, use electric dipole selection rules
- calculate scattering cross section within Born approximation

**Transferable/Key Skills and other attributes:**

On completion of this course students will be able to:

- use the adopted mathematical and physical methods for related problems in solid state physics, in soft matter physics and in biophysics
- use computer tools for analytical and numerical computation
- read scientific literature in the field of modern physics

**Metode poučevanja in učenja:**

Predavanja  
teoretične vaje  
razlaga  
razgovor  
delo s tekstom  
metoda pisnih in grafičnih del  
uporaba simulacij  
uporaba simulacijskih okolij

**Learning and teaching methods:**

Lectures  
Theoretical exercises  
Explanation  
Discussion  
Work with text  
Work with graphic elements  
Use of simulations  
Use of simulation software

Delež (v %) /

**Načini ocenjevanja:**

Weight (in %)

**Assessment:**

|   |     |  |
|---|-----|--|
| pisni izpit (lahko se nadomesti z 2 pisnima kolokvijema)  | 50% | Written exam (can be replaced by 2 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:

- MÉNESGUEN, Y., LÉPY, M. - C., ITO, Yoshiharu, YAMASHITA, M., FUKUSHIMA, S., TOCHIO, T., POLASIK, M., SLABKOWSKA, K., SYROCKI, L., INDELICATO, P., PADEŽNIK GOMILŠEK, Jana, MARQUES, J. P., SAMPAIO, J. M., MACHADO, J., AMARO, P., GUERRA, M., SANTOS, J. P., PARENTE, F. Structure of single  $KL_{0--}$ , double  $KL_{1--}$ , and triple  $KL_{2--}$  ionization in Mg, Al, and Si targets induced by photons, and their absorption spectra. *Radiation physics and chemistry*. 2022, vol. 194 (110048), ISSN 0969-806X. DOI: [10.1016/j.radphyschem.2022.110048](https://doi.org/10.1016/j.radphyschem.2022.110048). [COBISS.SI-ID [99607555](#)].
- 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*. 2020, vol. 171, str. 1-4, ISSN 0969-806X. DOI: [10.1016/j.radphyschem.2020.108743](https://doi.org/10.1016/j.radphyschem.2020.108743). [COBISS.SI-ID [5564411](#)].
- FOURATI, Emna, VOGEL-MIKUŠ, Katarina, WALI, Mariem, KAVČIČ, Anja, PADEŽNIK GOMILŠEK, Jana, KODRE, Alojz, KELEMEN, Mitja, VAVPETIČ, Primož, PELICON, Primož, ABDELLY, Chedly, GHNAYA, Tahar. Nickel tolerance and toxicity mechanisms in the halophyte *Sesuvium portulacastrum* L. as revealed by Ni localization and ligand environment studies. *Environmental science and pollution research*. 2019, vol. 27(19), 23402-23410. ISSN 0944-1344. DOI: [10.1007/s11356-019-05209-8](https://doi.org/10.1007/s11356-019-05209-8). [COBISS.SI-ID [5092687](#)].
- 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](https://doi.org/10.1103/PhysRevA.99.062501). [COBISS.SI-ID [22395158](#)].
- CERC KOROŠEC, Romana, UMEK, Polona, GLOTER, Alexandre, PADEŽNIK GOMILŠEK, Jana, BUKOVEC, Peter. Structural properties and thermal stability of cobalt- and chromium-doped  $\alpha$ - $MnO_2$  nanorods. *Beilstein journal of nanotechnology*. 2017, vol. 8, str. 1032-1042, ISSN 2190-4286. <https://www.beilstein-journals.org/bjnano/articles/8/104>, DOI: [10.3762/bjnano.8.104](https://doi.org/10.3762/bjnano.8.104). [COBISS.SI-ID [1537419971](#)].
- KOŠAK, Aljoša, BAUMAN, Maja, PADEŽNIK GOMILŠEK, Jana, LOBNIK, Aleksandra. Lead (II) complexation with 3-mercaptopropyl-groups in the surface layer of silica nanoparticles: Sorption, kinetics and EXAFS/XANES study. *Journal of molecular liquids*. [Print ed.]. March 2017, vol. 229, str. 371-379. ISSN 0167-7322. DOI: [10.1016/j.molliq.2016.11.115](https://doi.org/10.1016/j.molliq.2016.11.115). [COBISS.SI-ID [20042774](#)].

