



Univerza v Mariboru

Fakulteta za naravoslovje
in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS

Predmet:	Uvod v kvantno teorijo polja in fiziko delcev
Course title:	Introduction to quantum theory and particle physics

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
FIZIKA, 3. stopnja		1. ali 2.	1., 2. ali 4.
PHYSICS, 3 rd cycle		1. or 2.	1., 2. or 4.

Vrsta predmeta / Course type

Izbirni za vse module

Univerzitetna koda predmeta / University course code:

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Lab. vaje Laboratory work	Terenske vaje	Samost. delo Individ. work	ECTS
15					165	6

Nosilec predmeta / Lecturer:

Mirjam Cvetič

Jeziki /

Languages:

Predavanja /

Lectures:

Vaje / Tutorial:

slovenski/Slovenian in/and angleški s slovenskim
prevodom/English with translation in Slovenian

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

Ni posebnih zahtev.

Prerequisites:

No special prerequisites.

Vsebina:

- Klein-Gordonova enačba, simetrije pripadajočega Lagrangiana in druga kvantizacija delcev spina-0.
- Diracova enačba, njene simetrije in druga kvantizacija delcev s spinom $\frac{1}{2}$.
- Maxwelllova enačba, umeritvena simetrija, druga kvantizacija delcev s spinom 1.
- Tipi interakcij: skalarna, Yukawa-ina, umeritveno invariantne interakcije.

Content (Syllabus outline):

- Klein-Gordon equation, symmetries of the Lagrangian and second quantization of the spin-0 particles.
- Dirac equation, its symmetries and second quantization of spin $\frac{1}{2}$ particles.
- Maxwelllova equation, gauge symmetry, second quantization of spin 1 particles.

<ul style="list-style-type: none"> - Uvod v perturbativne izračune v kvantni teoriji polja, demonstrirano na delcih s spinom 0: <ul style="list-style-type: none"> a) Izpeljava tri-nivojskega Feynmanovega diagrama za S-matriko, b) reakcijski presek in izračun razpadov. - Perturbativni pristopi v kvantni elektrodinamiki: <ul style="list-style-type: none"> a) izpeljava Feynmanovih pravil s fermioni in polji spinov 1, b) izračuni za tipične primere sipalnih procesov in razpadov. - Vpeljava radiativnih popravkov in renormalizacija: <ul style="list-style-type: none"> a) vertex popravek, b) vakuumska polarizacija. - Aplikacije v sipalnih procesih v pospeševalnikih in sistemih fizike kondenzirane materije. 	<ul style="list-style-type: none"> - Types of interaction: scalar, Yukawa, gauge invariant interactions. - Interaction to the perturbative calculations in quantum field theory, demonstrated for spin 0 particles: <ul style="list-style-type: none"> a) Derivation of the three-level Feynman diagram for S-matrix, b) reakcijski presek in izračun razpadov. - Perturbative approaches in quantum electrodynamics: <ul style="list-style-type: none"> a) derivation of Feynman rules for fermions and fields for spin 1, b) calculations for typical examples of scattering processes and decays. - Introduction of radiative corrections and renormalization: <ul style="list-style-type: none"> a) vertex correction,, b) vacuum polarization. - Applications in scattering processes in accelerators and condensed matter systems.
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Temeljni literatura in viri / Readings:

Dütsch. (2019). *From Classical Field Theory to Perturbative Quantum Field Theory*. Springer International Publishing. **Celotno besedilo dostopno v SpringerLink Books**
<https://plus.cobiss.net/cobiss/si/sl/bib/4100000007810265>

Sadovskii, M. V. (2013). *Quantum Field Theory*. De Gruyter. **Celotno besedilo dostopno v EBSCOhost Ebook Academic Collection - World Wide**
<https://plus.cobiss.net/cobiss/si/sl/bib/2550000001097070>

Morii, T. (2004). *Physics Of The Standard Model And Beyond*. World Scientific Publishing Company. **Celotno besedilo dostopno v EBSCOhost Ebook Academic Collection - World Wide**
<https://plus.cobiss.net/cobiss/si/sl/bib/1000000000537866>

CVETIČ, Mirjam, GIBBONS, G. W., POPE, Christopher N., WHITING, B. F. Positive energy functional for massless scalars in rotating black hole backgrounds of maximal ungauged supergravity. *Physical review letters online*. [Online ed.]. jun. 2020, vol. 124, issue 23, art. 231102, graf. prikazi. ISSN 1079-7114. DOI: 10.1103/PhysRevLett.124.231102. [COBISS.SI-ID 20844291]

Dodatna:

- 1) Weinberg, S. (2005). *The quantum theory of fields, Volume 1: Foundations*. Cambridge University Press. ISBN-13: 978-0521670531

- 2) Srednicki, M. (2007). *Quantum field theory*. Cambridge University Press. ISBN-13: 978-0521864497
- 3) Ramond, P. (2001). *Field theory: A modern primer* (Frontiers in Physics Series, Vol. 74). Westview Press. ISBN-13: 978-0201304503
- 4) Langacker, P. (2009). *The standard model and beyond* (Series in High Energy Physics, Cosmology and Gravitation). Taylor and Francis. ISBN-13: 978-1420079067
- 5) Cvetič, M., & Langacker, P. (1991). *Testing the Standard Model: Proceedings of the 1990 Theoretical Advanced Study Institute in Elementary Particle Physics*. World Scientific Publishing. ISBN-13: 978-9810203146

Cilji in kompetence:

- Razumeti principe, metode in rezultate kvantne teorije polja
- Znati uporabljati metode
- Pridobiti si sposobnost nadaljnega samostojnega študija fizike visokih energij

Objectives and competences:

- Understanding of principles, methods and results of the quantum field theory
- Gaining skills to use the methods
- Gaining the ability of individual independent further study of the high energy physics

Predvideni študijski rezultati:

Znanje in razumevanje:

- Znanje principov, metod in rezultatov kvantne teorije polja
- Razumevanje rezultatov in njihove uporabe

Prenosljive/ključne spretnosti in drugi atributi:

- Sposobnost samostojnega dela in študija
- Uporaba znanj na drugih področjih

Intended learning outcomes:

Knowledge and understanding:

- Understanding of principles, methods and results of the quantum field theory
- Understanding of the results and their applications

Transferable/Key Skills and other attributes:

- Ability to perform individual work and study
- Ability to apply the knowledge in other fields

Metode poučevanja in učenja:

Predavanja, seminar

Learning and teaching methods:

Lectures, seminar

Delež (v %) /

Weight (in %)

Načini ocenjevanja:

Način (pisni izpit, ustno izpraševanje, naloge, projekt)

- Ustni izpit
- Projekt

50%
50%

Assessment:

Type (examination, oral, coursework, project):

- Oral exam
- Project

Reference nosilca / Lecturer's references:

- 1.** Mirjam Cvetič, Nelson Hernández Rodríguez, Maria J Rodriguez, Oscar Varela, Kerr effective black hole geometries in supergravity, *Physical Review D*, 112, 2025, 026007
- 2.** CVETIČ, Mirjam, GIBBONS, G. W., POPE, Christopher N., WHITING, B. F. Positive energy functional for massless scalars in rotating black hole backgrounds of maximal ungauged supergravity. *Physical review letters online*. [Online ed.]. jun. 2020, vol. 124, issue 23, art. 231102, graf. prikazi. ISSN 1079-7114. DOI: 10.1103/PhysRevLett.124.231102. [COBISS.SI-ID 20844291]
- 3.** Mirjam Cvetič, Ron Donagi, Jonathan J Heckman, Max Hübner, Ethan Torres, Cornering relative symmetry theories, *Physical Review D* 111, 2025., 085026