COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
(Concepts of) Quantum Field Theory	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: Thomas Gajdosik **Other(s):**	Teorinės fizikos ir astronomijos institutas

Study cycle	Type of the course unit (module)
Master studies	selectable lecture

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Lecture	Fall semester: September till December	English

Requirements for students	
Prerequisites: Quantum Mechanics, Special Relativity	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	52	88

Purpose of the course unit (module): programme competences to be developed		
Students should learn the basic mathematical formulations that are necessary for Quantum Field Theory. Based on that ground work, the student should be able to understand the mathematical formulation of the Standard Model of particle physics and should grasp what can be formulated beyond the Standard Model.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
Special Relativity, calculating the kinematics of decays or scattering processes with relativistic particles	Lecture and reading (self study)	home work, exam
Concepts of Quantum Field Theory	Lecture and reading (self study)	exam
Gauge Theories	Lecture and reading (self study)	exam
The Standard Model (SM) of particle physics	Lecture and reading (self study)	exam
Beyond the SM: Concepts of Supersymmetry and of string theory	Lecture and reading (self study)	exam

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Special Relativity Repetition: Invariants, Lorentztransformations, Poincare group [1, 2]; Introduction to Special Relativity and the Poincare algebra	2		1				**3**	**2** **2**	Repeating, reading Homework 1 3.1 %

2. Special Relativity: Spinors [2, 7] differential operators implementing the group structure of translations and rotations; spinors as representations of the rotation group; discussion of the group structure of the Poincare algebra	2		1				**3**	**2** **2**	Repeating, reading Homework 2 2.8 %
3. SR kinematics: [2] Calculating decays and scattering processes with relativistic particles			2				**2**	**2** **3**	Reading Homework 3 3.6 %
4. Quantum Field Theory (QFT): Approaches: canonical, path-integral [4, 6, 8, 9, 15] explaining the conceptual basis for the quantisation procedures in field theory	2		2				**4**	**7**	Repeating, reading
5. QFT: Feynman diagrams [2, 4, 5, 6, 8, 9] deriving Feynman diagrams as the perturbative expansion of the scattering amplitude that was introduced in the previous lecture	2		2				**4**	**7** **2**	Repeating, reading Homework 4 4.2 %
6. QFT: Renormalisation [4, 6, 8, 9, 10] showing the need for renormalisation as the connection between theory and expermient; giving an example of renormalisation in the scalar ABC-toy-model	2		2				**4**	**7**	Repeating, reading
7. QFT: Gauge theory [4, 6, 8, 9, 13] discussing general properties of gauge theories; introducing gauge fixing as a possibility to define the propagator; quantising the gauge field in the path-integral formalism, including the proper treatment of gauge-fixing	2		2				**4**	**7**	Repeating, reading
8. Quantum Electro Dynamics (QED) [4, 6, 8, 9, 13] renormalising quantum electro dynamics and discussing the elementary one-particle-irreducible diagram, including dimensional regularisation; evaluation of the photon propagator gives the Lamb-shift in the low energy approximation	2		2				**4**	**9**	Repeating, reading
9. Quantum Chromo Dynamics (QCD) [4,6,8,9,13] energy dependent evaluation of the vector boson propagator leads to an understanding of the running coupling constant; further analysis gives the renormalisation group equation; renormalising QCD shows the opposite sign of the beta function which explains asymptotic freedom and confinement; discussing parton distribution functions as an effective renormalisation prescription for the analysis of high energy collider experiments	2		2				**4**	**9**	Repeating, reading
10. The Standard Model: Particle content [2, 3, 14] An overview over the Standard Model (SM) and its particles	2		2				**4**	**4** **4**	Repeating, reading Homework 5 5 %
11. SM: Higgs Mechanism [2, 3, 14] explanation of the Higgs mechanism in the electro-weak Standard Model	2		2				**4**	**7**	Repeating, reading
12. SM: Particle detection [2, 3] discussing, how we can connect the classical approach of the expermiental detectors with the quantum nature of the detected particles; principle mechanisms for detecting particles; overview over the CMS detector	2		2				**4**	**4**	Repeating, reading

13. Beyond the SM: Supersymmetry (SUSY) — MSSM [4, 12, 13, 16] discussing supersymmetry as an extension of the Poincar ́e algebra; motivating the construction of a supersymmetric field theory; applying the principles to construct schematically the minimal supersymmetric Standard Model (MSSM); discussing the relevance of the MSSM to grand unification and to cosmology; motivating supergravity	2		2				**4**	**3**	Repeating, reading
14. Beyond the SM: Strings, Stringtheory, Superstrings [12, 17] history and concepts of string theory; introducing the bosonic string; motivating the introduction of superstrings; branes as boundary conditions, becoming dynamical objects; discussing compactification and dualities, leading to the conjecture of M-theory	2		2				**4**	**3**	Repeating, reading
Preparing the seminar presentation								**2**	
Total	**26**		**26**				**52**	**88**	

Assessment strategy	**Weight,%**	**Deadline**	**Assessment criteria**
Participation in the lecture and discussion during the seminars	13 %		Active participation
Homeworks	20 %	As announced in the syllabus:	Turing in the homework and correcting it
Seminar presentation	15 %		Giving the presentation
Exam	52 %		Passing the written and the oral part

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsary reading				
1. Davig Hoggt	1997	Special Relativity		http://cosmo.nyu.edu/hogg/sr/sr.pdf
2. David Griffiths	1987	Introduction to Elementary Particles		John Wiley & Sons, Inc.; ISBN 0-471-60386-4 (1987).
3. Particle Data Group	2014	The particle adventure:		http://www.particleadventure.org/
4. A. Zee	2003	Quantum Field Theory in a Nutshell		Princeton University Press; ISBN 0-691-01019-6 (2003).
5 J. C. Romao and J. P. Silva	2012	A resource for signs and Feynman diagrams of the Standard Model		arXiv:1209.6213 [hep-ph]
Optional reading				
6. Michael E. Peskin and Daniel V. Schroeder	1995	An Introduction to Quantum Field Theory;		Reading, USA: Addison-Wesley; ISBN 0-201-50397-2
7. P. B. Pal	2010	Dirac, Majorana and Weyl fermions		arXiv:1006.1718 [hep-ph]
8. I. J. R. Aitchison and A. J. G. Hey	2013	Gauge theories in particle physics: A practical introduction. Vol. 1: From relativistic quantum mechanics to QED		Bristol, UK: IOP (2003) 406p
9. I. J. R. Aitchison and A. J. G. Hey	2014	Gauge theories in particle physics: A practical introduction. Vol. 2: Non-Abelian gauge theories: QCD and the electroweak theory		Bristol, UK: IOP (2004) 454 p

10. F. Olness and R. Scalise	2011	Regularization, Renormalization, and Dimensional Analysis: Dimensional Regularization meets Freshman E & M	Am. J. Phys. 79 (2011) 306	[arXiv:0812.3578 [hep-ph]]
11. David Tong	2007	Quantum Field Theory, University of Cambridge Part III Mathematical Tripos		http://www.damtp.cam.ac.uk/user/tong/qft/qft.pdf
12. Warren Siegel	2017	Fields		http://arxiv.org/abs/hep-th/9912205 or http://insti.physics.sunysb.edu/~siegel/Fields4.pdf
13. Stefan Pokorsky	2000	Gauge Field Theories		Cambridge University Press; ISBN 0-521-47816-2 (2000)
14. F. Jegerlehner	1991	Renormalizing The Standard Model		PSI-PR-91-08, Apr 1991
15. S. Weinberg	1995	The Quantum Theory of Fields, I and II,		Cambridge University Press; ISBN 0-521-58555-4
16. S. Weinberg	2000	The Quantum Theory of Fields, III		Cambridge University Press; ISBN 0-521-66000-9
17. Matthew D. Schwartz	2014	Quantum Field Theory and the Standard Model		Cambridge University Press; ISBN 9781107034730