

(Table 5.2) Course unit description

Study program: Physics			
Type and level of studies: Doctoral studies			
Course unit: Open quantum systems theory			
Teacher in charge: Miroljub Dugić/Momir Arsenijević			
Language of instruction: English			
ECTS: 15			
Prerequisites: Enrolled semester			
Semester: winter semester			
Course unit objective The students will be familiarized with the basic concepts and fundamentals of modern open systems theory as well as basic models. Ubiquity of openness of quantum systems, starting from the systems as simple as the hydrogen atom, is the main qualitative objective of the course. Universal applicability of the theory is particularly emphasized in physics, chemistry, materials science and quantum biology.			
Learning outcomes of Course unit The students will be able to work independently in research and in critical assessment of the others' research results in the foundations and some basic applications of the theory.			
Course unit contents Theoretical classes Banach space and operations. Closed versus open quantum systems. Dynamical maps: positivity, complete positivity (Jamiolkowski and the alternative criteria for finite-dimensional spaces) and trace preservation. Universal dynamical maps and contractions; the inverse of a universal dynamical map. Markov processes: Chapman-Kolmogorov criterion in a quantum form. Differential form of Markovian dynamics; semigroups and the Lindblad form of master equations. Nakajima-Zwanzig projection method. Markovian dynamics as a limiting case of the weak-coupling and the singular-coupling limit. Steady states of homogeneous Markov processes. Quantum optical master equation. Quantum Brownian motion (Caldeira-Leggett model); decoherence versus friction. Damped harmonic oscillator. Continuous variable systems: Gaussian states as the approximate pointer basis states. Outlook: non-Markovian dynamics.			
Literature Á. Rivas, S. F. Huelga, "Open quantum systems. An introduction", Springer Briefs in Physics, Springer 2011; also available at http://arxiv.org/abs/1104.5242 . 2. H.-P. Breuer, F. Petruccione, "The theory of open quantum systems", Clarendon Press, Oxford, 2002. <i>Additional literature:</i> 3. Á. Rivas, S. F. Huelga, M. B. Plenio, "Quantum non-Markovianity: characterization, quantification and detection", <i>Reports on Progress in Physics</i> 77, 094001 (2014); also available at http://arxiv.org/abs/1405.0303 .			
Number of active teaching hours			Other classes:
Lectures:	Practice:	Other forms of classes: Mentor system 75 Independent work: 30	
Teaching methods: lectures, seminars, exercises			
Examination methods (maximum 100 points)			
Exam prerequisites	No. of points	Final exam	No. of points
Practical classes		Written examination	

Tests		Oral examination	40
Homework	30	Other	
Seminars	30		
Project			
Grading system			
Grade	No. of points		Description
10	≥ 91		Excellent
9	81-90		Exceptionally good
8	71-80		Very good
7	61-70		Good
6	51-60		Passing
5	≤ 50		Failing