Subject card

Subject name and code	Numerical Methods, PG_00159207		
Field of study	Quantum Information Technology		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2026/2027
Education level	Master’s studies	Subject group	
Mode of study	full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	English
Semester of study	3	ECTS credits	6.0
Learning profile	academic	Assessment form	exam
Conducting unit	Faculty of Mathematics, Physics and Informatics -> Rector		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. inż. Piotr Mironowicz	
	Teachers		

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	30.0	0.0	0.0	0.0	60
	E-learning hours included: 0.0						

Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	60	0.0	30.0	90

Subject objectives	This course is an advanced course of numerical methods for quantum information. To explore quantum information one require computational methods since mathematical models are only rarely solvable algebraically. Numerical methods, based upon computational mathematics and quantum physics, are the basic algorithms enabling computer predictions in quantum information. Such methods include techniques for optimization, linear algebra underlying eigenvalue problem, stochastic simulation.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[QITL3_W02] has in-depth knowledge in the field of advanced mathematics and mathematical and computer methods, necessary to solve physical problems of medium complexity, and advanced knowledge in the area of quantum information and its technological aspects	Student knows methods used to simulate many-body systems.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
	[QITL3_W05] knows the theoretical foundations of computational methods and IT techniques used to model and simulate physical systems considered in quantum information theory	Student knows stochastic simmulation methods and understands their rationale.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
	[QITL3_W06] has knowledge of current directions in the development of physics, in particular in the field of quantum information theory	Student knows about newest developments in numerical optimization methods.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
	[QITL3_W03] knows advanced experimental, observational and numerical techniques allowing to plan and perform a complex physical experiment or computer simulation	Student knows how to do numerical calculations and simulations to solve many-body differential equations.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
	[QITL3_U05] has the ability to synthesize methods and ideas from various areas of physics and other branches of science; is able to notice that distant phenomena are sometimes described by similar models	Student has the ability to connect analytical methods of open quantum systems and techniques for their numerical simmulation with tools used in different areas of physics	[SU4] test/exam - oral or written [SU5] implementation of a problem task

Subject contents	
	Optimization: basic concepts, computational complexity. Linear programming: simplex method, duality and sensitivity. Unconstrained optimization: method of steepest descent, Newtons method, conjugate gradient algorithm; linear least squares, robust optimization. Constrained optimization: projected gradient methods; sequential unconstrained minimization, convex optimization, nonlinear optimization. Combinatorial optimization: simulated annealing. Maximum likelihood estimation. Evolutionary algorithm. Singular value decomposition, the pseudo-inverse. Matrix eigenvalues: Jacobis method, Givens transformation, Householder transformation, the LR method, the QR method. Maximum (minimum) modulus eigenvalue: power method, inverse power iteration, shifted inverse power iteration. The general eigenvalue problem. Numerical methods for sampling from a given density Numerical simulations of master equations. Software for optimization, eigenproblem solution and stochastic simulations.

Prerequisites and co-requisites	Passing Programming course at semester 1.		
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	lecture part: exam	51.0%	50.0%
	tutorial part: test	51.0%	50.0%
Recommended reading	Basic literature	G. S. Chirikjian, Stochastic Models, Information Theory, Analytic Methods and Modern Applications and Lie Groups,Vol. 2, Analytic Methods and Modern Applications, Springer Science+Business Media, 2012 S. Butenko, P.M. Pardalos, Numerical Methods and Optimization, An Introduction, Taylor & Francis Group 1014 S. K. Bose, Numerical Methods of Mathematics Implemented in Fortran, Springer Nature Singapore Pte Ltd. 2019 A. Kharab, R. B. Guenther, An Introduction to Numerical Methods, A MATLAB Approach, Taylor & Francis Group, 2019 É. Walter, Numerical Methods and Optimization, A Consumer Guide, Springer International Publishing Switzerland 2014 G. Lindfield, J. Penny, Numerical Methods Using MATLAB, Elsevier 2019 R. Toral, P. Colet, Stochastic Numerical Methods, An Introduction for Students and Scientists, Wiley-VCH 2014 R. K. Gupta, Numerical Methods Fundamentals and Applications, Cambridge University Press 2019	
	Supplementary literature	None.	
	eResources addresses		
Example issues/ example questions/ tasks being completed			
Work placement	Not applicable		

Document generated electronically. Does not require a seal or signature.