University of Gdańsk

Subject card

Subject name and code	Numerical Methods, PG_00159207						
Field of study	Quantum Information Technology						
Date of commencement of studies	October 2024		Academic year of realisation of subject	2025/2026			
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				
Conducting unit	Faculty of Mathematics, Physics and Informatics -> Rector						
Name and surname of lecturer (lecturers)	Subject supervisor		dr 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_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
[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_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_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_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

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.

<table>
<tr><td>Prerequisites and co-requisites</td><td colspan="2">Passing Programming course at semester 1.</td></tr>
<tr><td>Assessment methods and criteria</td><td colspan="2"><table>
<tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr>
<tr><td>tutorial part: test</td><td>51.0%</td><td>50.0%</td></tr>
<tr><td>lecture part: exam</td><td>51.0%</td><td>50.0%</td></tr>
</table></td></tr>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td>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</td></tr>
<tr><td>Supplementary literature</td><td>None.</td></tr>
<tr><td>eResources addresses</td><td>Adresy na platformie eNauczanie:</td></tr>
<tr><td>Example issues/ example questions/ tasks being completed</td><td colspan="2"></td></tr>
<tr><td>Work placement</td><td colspan="2">Not applicable</td></tr>
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