Study plan

Name of study plan: Quantum Informatics

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department:
Garantor of the study branch: prof. Ing. Róbert Lórencz, CSc.
Program of study: Quantum Informatics
Type of study: Follow-up master full-time
Required credits: 120
Elective courses credits: 0
Sum of credits in the plan: 120
Note on the plan:

Name of the block: Compulsory courses in the program
Minimal number of credits of the block: 96
The role of the block: PP

Code of the group: QNIE-PP
Name of the group: Compulsory courses of the Quantum Informatics
Requirement credits in the group: In this group you have to gain 96 credits
Requirement courses in the group: In this group you have to complete 12 courses
Credits in the group: 96
Note on the group:

Code	**Name of the course / Name of the group of courses** ***(in case of groups of courses the list of codes of their members)*** *Tutors,* ***authors*** *and guarantors (gar.)*	Completion	Credits	Scope	Semester	Role
QNIE-DIP	**Diploma Thesis**	Z	30	270ZP	L,Z	PP
QNIE-KKP	**Cryptology and Quantum Computing** ***Róbert Lórencz***	Z,ZK	6	2P+2C		PP
BQM32KOS	**Quantum optical communications and networks** *Jiří Weiss, Václav Prajzler, Jan Voves, Leoš Boháč* ***Jiří Weiss*** *Leoš Boháč (Gar.)*	Z,ZK	6	2P+2L	L	PP
QNIE-QC1	**Quantum Computation 1**	Z,ZK	6	2P+2C	Z	PP
QNIE-QC2	**Quantum Computing 2**	Z,ZK	6	2P+2C	L	PP
QNIE-LOM	**Linear Optimization and Methods** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+1C	Z	PP
QNIE-MPR	**Master Project** ***Zdeněk Muzikář***	Z	7		Z,L	PP
QNIE-MQI	**Mathematics for Quantum Informatics**	Z,ZK	6	2P+2C	Z	PP
QNIE-PPS	**Programming of parallel systems**	Z,ZK	6	2P+2C		PP
QNIE-TIN	**Information Theory**	Z,ZK	6	2P+2C	L	PP
QNIE-CPX	**Complexity Theory** ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	6	3P+1C	Z	PP
QNIE-UKT	**Introduction to Quantum Theory**	Z,ZK	6	2P+2C	Z	PP

Characteristics of the courses of this group of Study Plan: Code=QNIE-PP Name=Compulsory courses of the Quantum Informatics

QNIE-DIP	Diploma Thesis	Z	30

Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile.

QNIE-KKP	Cryptology and Quantum Computing	Z,ZK	6

The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last lectures deal with cryptosystems using quantum phenomena.

BQM32KOS	Quantum optical communications and networks	Z,ZK	6
TThe goal of this course is to provide a comprehensive engineering insight into optical communications, with a specific focus on Quantum Key Distribution (QKD). The subject breaks down boundaries between traditional disciplines, integrating knowledge of wave optics, hardware architecture, and network security. Students will learn to perceive the communication system as a holistic entity, where the physical layer directly defines the limits and capabilities of digital security. The course prepares students for the real-world challenges associated with deploying quantum technologies into existing telecommunications infrastructure.			
QNIE-QC1	Quantum Computation 1	Z,ZK	6
The course introduces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum computation uses quantum circuits, which will be demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its visualization, measurements, basic gates and their composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the properties of quantum states. The course will also cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estimation algorithm, and the Shor algorithm.			
QNIE-QC2	Quantum Computing 2	Z,ZK	6
Quantum Computing 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algorithms solving linear algebra problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error correction.			
QNIE-LOM	Linear Optimization and Methods	Z,ZK	5
Students will gain an overview of applications of optimization methods in computer science, economics and industrial practice. They will be introduced to the practical importance of linear and integer programming. They will be able to work with optimization software and to master the languages used in its programming. They will be able to formalise optimisation problems in the areas of computer science (e.g. task allocation to processors, network flow analysis), resource distribution and allocation (traffic problems, business traveller problem, etc.). Gain an overview of computational complexity issues in optimization. Gain a good understanding of linear programming algorithms and selected integer linear programming algorithms.			
QNIE-MPR	Master Project	Z	7
1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester.			
QNIE-MQI	Mathematics for Quantum Informatics	Z,ZK	6
Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization, diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform.			
QNIE-PPS	Programming of parallel systems	Z,ZK	6
Nowadays, multi-core processors and GPU accelerators have become common components of computing clusters and high-performance computing systems, so knowledge and skills related to parallel programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming methods of parallel computers with shared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to combine parallelization techniques at all three levels. Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundamental parallel algorithms and be able to analyze the limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In addition to the necessary theory in lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments.			
QNIE-TIN	Information Theory	Z,ZK	6
The course focuses on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The coding problem is addressed probabilistically, the relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case of the noisy channel we focus on the set of typical sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as conditional distributions, goodness-of-fit and independence tests, and an introduction to random chains.			
QNIE-CPX	Complexity Theory	Z,ZK	6
Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.			
QNIE-UKT	Introduction to Quantum Theory	Z,ZK	6
interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode of a quantized electromagnetic field.			

Name of the block: Compulsory elective courses
Minimal number of credits of the block: 24
The role of the block: PV

Code of the group: QNIE-PV
Name of the group: Compulsory elective courses of the QNIE Quantum Informatics programme
Requirement credits in the group: In this group you have to gain at least 24 credits (at most 68)
Requirement courses in the group: In this group you have to complete at least 4 courses (at most 13)
Credits in the group: 24
Note on the group: Beware of the knowledge prerequisite of the QNI-QML course. You can enroll only with the previous knowledge, which is discussed in the following bachelor's courses: BI-ML1.21 Strojové učení 1 BI-ML2.21 Strojové učení 2

Code	**Name of the course / Name of the group of courses** ***(in case of groups of courses the list of codes of their members)*** *Tutors, **authors** and guarantors (gar.)*	Completion	Credits	Scope	Semester	Role
BQM36AVM	**Adiabatic computing and variational methods** *Jakub Mareček **Jakub Mareček** Jakub Mareček (Gar.)*	Z,ZK	6	2P+2C		PV

BQM36QTC	**Quantum (State, Process, Channel) Tomography and Quantum Optimal Control** *Jakub Mareček* ***Jakub Mareček*** *Jakub Mareček (Gar.)*	Z,ZK	6	2P+2C		PV
BQM36KPB	**Quantum computing in banking** *Jakub Mareček* ***Jakub Mareček*** *Jakub Mareček (Gar.)*	Z,ZK	5	2P+2C		PV
QNIE-NMK	**Numerical methods for quantum computation**	Z,ZK	5	2P+2C		PV
QNIE-OQC	**Optical quantum computing**	Z,ZK	5	2P+1C	Z	PV
QNIE-OVV	**Optimization for Scientific Computing**	Z,ZK	5	2P+1C		PV
QNIE-PNM	**Parallelization of numerical methods**	Z,ZK	5	2P+2C		PV
QNIE-PJK	**Programming languages for quantum computing** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	L	PV
QNIE-QEC	**Quantum error correction**	Z,ZK	5	2P+2C	Z	PV
QNIE-QML	**Quantum machine learning**	Z,ZK	5	2P+1C	Z	PV
QNIE-QOM	**Quantum Optics, Metrology, Sensing and Imaging**	Z,ZK	5	2P+2C	Z	PV
QNIE-PON	**Selected Topics in Optimization and Numerical mathematics**	Z,ZK	5	2P+1C	L	PV

Characteristics of the courses of this group of Study Plan: Code=QNIE-PV Name=Compulsory elective courses of the QNIE Quantum Informatics programme

BQM36AVM	Adiabatic computing and variational methods	Z,ZK	6
BQM36QTC	Quantum (State, Process, Channel) Tomography and Quantum Optimal Control	Z,ZK	6
BQM36KPB	Quantum computing in banking	Z,ZK	5
QNIE-NMK	Numerical methods for quantum computation	Z,ZK	5
	The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.		
QNIE-OQC	Optical quantum computing	Z,ZK	5
	The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.		
QNIE-OVV	Optimization for Scientific Computing	Z,ZK	5
	The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.		
QNIE-PNM	Parallelization of numerical methods	Z,ZK	5
	The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.		
QNIE-PJK	Programming languages for quantum computing	Z,ZK	5
	Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper).). In the seminars the student will learn the basics of programming in the higher programming language Silq.		
QNIE-QEC	Quantum error correction	Z,ZK	5
	In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized, atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.		
QNIE-QML	Quantum machine learning	Z,ZK	5
	The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.		
QNIE-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5
	Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.		
QNIE-PON	Selected Topics in Optimization and Numerical mathematics	Z,ZK	5
	Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.		

Name of the block: Elective courses
Minimal number of credits of the block: 0
The role of the block: V

Code of the group: QNIE-V
Name of the group: Purely Elective Master's Courses in the academic programme Quantum Informatics
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0

Note on the group: In addition to the courses listed here, you can enroll as an elective any course that is offered within your study program and form of study that you did not enroll as a compulsory subject in the program/branch/specialization or a compulsory elective course.Courses of this group that a student has completed in the bachelor study at CTU cannot be re-completed.

Code	**Name of the course / Name of the group of courses** ***(in case of groups of courses the list of codes of their members)*** *Tutors,* ***authors*** *and guarantors (gar.)*	Completion	Credits	Scope	Semester	Role
QNIE-AVM	**Adiabatic computing and variational methods**	Z,ZK	6	2P+2C	*	v
NIE-KRY	**Advanced Cryptology** *Róbert Lórencz, Jiří Buček* ***Jiří Buček*** *Róbert Lórencz (Gar.)*	Z,ZK	5	2P+2C	Z	v
NIE-AOS	**Advanced Operating Systems**	Z,ZK	5	2P+1C	Z	v
NIE-APT	**Advanced Program Testing** *Pierre Donat-Bouillud* ***Pierre Donat-Bouillud*** *Pierre Donat-Bouillud (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-AIB	**Algorithms of Information Security** *Martin Jureček* ***Martin Jureček*** *Martin Jureček (Gar.)*	Z,ZK	5	2P+1C	Z	v
FIT-BIP	**Blended Intensive Programme** ***Zdeněk Muzikář*** *Zdeněk Muzikář (Gar.)*	Z	3		Z,L	v
NIE-BLO	**Blockchain** *Josef Gattermayer, Marek Bielik, Jakub Růžička* ***Josef Gattermayer*** *Josef Gattermayer (Gar.)*	Z,ZK	5	1P+2C	Z	v
NIE-GEN	**Code Generators** *Petr Máj* ***Petr Máj*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-CPX.26	**Complexity Theory** ***Dušan Knop***	Z,ZK	6	3P+1C	Z	v
NIE-KOD	**Data Compression** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)*	Z,ZK	5	2P+1C	L	v
NIE-DSS	**Decision Support Systems** *Robert Pergl, Petra Pavlíčková* ***Petra Pavlíčková*** *Robert Pergl (Gar.)*	Z,ZK	5	2P+1C	Z	v
FITE-DIF	**Differential equations** *Ondřej Bouchala, Antonella Marchesiello, Jan Valdman Ondřej Bouchala (Gar.)*	Z,ZK	5	2P+2C	L	v
ANIE-SIM	**Digital Circuit Simulation and Verification**	Z,ZK	5	2P+1C	Z	v
NIE-DSV	**Distributed Systems and Computing** *Pavel Tvrdík, Peter Macejko* ***Peter Macejko*** *Pavel Tvrdík (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-EPC	**Effective C++ programming** *Daniel Langr* ***Daniel Langr*** *Daniel Langr (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-EVY	**Efficient Text Pattern Matching** *Jan Holub* ***Jan Holub*** *Jan Holub (Gar.)*	Z,ZK	5	2P+1C	Z	v
ANIE-EHW	**Embedded Hardware**	Z,ZK	5	2P+2C	L	v
ANIE-BVS	**Embedded Security**	Z,ZK	5	2P+2C	L	v
ANIE-ESW	**Embedded Software**	Z,ZK	5	2P+2C	Z	v
ANIE-BKO	**Error Control Coding**	Z,ZK	5	2P+1C	L	v
QNIE-VOT	**Fiber Optic Technology**	Z,ZK	6	2P+2C		v
NIE-GPU	**GPU Architectures and Programming** *Ivan Šimeček* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)*	Z,ZK	5	2P+1C	L	v
NIE-GAK.26	**Graph theory and combinatorics**	Z,ZK	6	2P+2C	L	v
NIE-HWB	**Hardware Security** *Jiří Buček* ***Jiří Buček*** *Jiří Buček (Gar.)*	Z,ZK	5	2P+2C	L	v
FITE-EHD	**Introduction to European Economic History** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	3	2P+1C	L	v
NIE-LOM	**Linear Optimization and Methods** *Dušan Knop* ***Dušan Knop*** *Dušan Knop (Gar.)*	Z,ZK	5	2P+0S+1C	Z	v
ANIE-MLM	**Machine Learning Methods**	Z,ZK	5	2P+1C		v
NIE-MKY.26	**Mathematics for Cryptology** ***Róbert Lórencz***	Z,ZK	7	3P+2C	L	v
NIE-MPS	**Modern Computer Networks** ***Jan Fesl***	Z,ZK	5	2P+2C	Z	v
NIE-MCC	**Multicore CPU Computing** *Daniel Langr, Ivan Šimeček* ***Ivan Šimeček*** *Ivan Šimeček (Gar.)*	Z,ZK	5	2P+1C	Z	v
ANIE-COM	**Network Communication** *Tomáš Čejka* ***Tomáš Čejka*** *Tomáš Čejka (Gar.)*	Z,ZK	5	2P+1C		v
NIE-SIB	**Network Security** *Simona Fornůsek, Jiří Dostál, Tomáš Zahradnický, Gramoz Cubreli* ***Simona Fornůsek*** *Simona Fornůsek (Gar.)*	Z,ZK	5	2P+1C	L	v
QNIE-NMK	**Numerical methods for quantum computation**	Z,ZK	5	2P+2C		v
QNIE-OPM	**Optical measurements**	Z,ZK	6	2P+2C		v
QNIE-OQC	**Optical quantum computing**	Z,ZK	5	2P+1C	Z	v
QNIE-OVV	**Optimization for Scientific Computing**	Z,ZK	5	2P+1C		v

QNIE-PNM	**Parallelization of numerical methods**	Z,ZK	5	2P+2C		v
NIE-PAM	**Parameterized Algorithms** *Ondřej Suchý* ***Ondřej Suchý*** *Ondřej Suchý (Gar.)*	Z,ZK	4	2P+1C	L	v
NIE-SYP	**Parsing and Compilers** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-PML	**Personalized Machine Learning** *Rodrigo Augusto Da Silva Alves* ***Karel Klouda*** *Rodrigo Augusto Da Silva Alves (Gar.)*	Z,ZK	5	2P+1C	Z	v
NIE-PDL	**Practical Deep Learning** *Martin Barus, Yauhen Babakhin* ***Karel Klouda*** *Karel Klouda (Gar.)*	KZ	5	2P+1C	Z	v
QNIE-PJK	**Programming languages for quantum computing** *Jan Janoušek* ***Jan Janoušek*** *Jan Janoušek (Gar.)*	Z,ZK	5	2P+1C	L	v
FIT-PMA	**Programming in Mathematica** *Zdeněk Buk* ***Zdeněk Buk*** *Zdeněk Buk (Gar.)*	Z,ZK	4	2P+2C	Z,L	v
QNIE-QEC	**Quantum error correction**	Z,ZK	5	2P+2C	Z	v
QNIE-QML	**Quantum machine learning**	Z,ZK	5	2P+1C	Z	v
QNIE-KOS	**Quantum Optical Communications and Networks**	Z,ZK	6	2P+2C		v
QNIE-QOM	**Quantum Optics, Metrology, Sensing and Imaging**	Z,ZK	5	2P+2C	Z	v
NIE-REV	**Reverse Engineering** *Josef Kokeš* ***Josef Kokeš*** *Josef Kokeš (Gar.)*	Z,ZK	5	1P+2C	Z	v
NIE-RUN	**Runtime Systems** *Filip Křikava, Filip Říha* ***Filip Křikava*** *Filip Křikava (Gar.)*	Z,ZK	5	2P+1C	L	v
NIE-APR	**Selected Methods for Program Analysis** ***Filip Křikava***	Z,ZK	5	2P+1C	Z	v
QNIE-PON	**Selected Topics in Optimization and Numerical mathematics**	Z,ZK	5	2P+1C	L	v
NIE-SEM	**Semantics of Programming Languages**	Z,ZK	5	2P+1C	Z	v
NIE-SBF	**System Security and Forensics** *Jiří Buček, Simona Fornůsek, Tomáš Zahradnický, Marián Svetlík* ***Simona Fornůsek*** *Simona Fornůsek (Gar.)*	Z,ZK	5	2P+1C	Z	v
ANIE-TSP	**Testing and Reliability**	Z,ZK	5	2P+2C	Z	v
NIE-VCC	**Virtualization and Cloud Computing** *Tomáš Vondra* ***Tomáš Vondra*** *Tomáš Vondra (Gar.)*	Z,ZK	5	2P+1C	L	v
FITE-SEP	**World Economy and Business** *Tomáš Evan* ***Tomáš Evan*** *Tomáš Evan (Gar.)*	Z,ZK	4	2P+2C	Z	v

Characteristics of the courses of this group of Study Plan: Code=QNIE-V Name=Purely Elective Master's Courses in the academic programme Quantum Informatics

QNIE-NMK	Numerical methods for quantum computation	Z,ZK	5

The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.

QNIE-OQC	Optical quantum computing	Z,ZK	5

The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.

QNIE-OVV	Optimization for Scientific Computing	Z,ZK	5

The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.

QNIE-PNM	Parallelization of numerical methods	Z,ZK	5

The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.

QNIE-PJK	Programming languages for quantum computing	Z,ZK	5

Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper).). In the seminars the student will learn the basics of programming in the higher programming language Silq.

QNIE-QEC	Quantum error correction	Z,ZK	5

In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized, atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.

QNIE-QML	Quantum machine learning	Z,ZK	5

The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.

QNIE-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5

Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.

QNIE-PON	Selected Topics in Optimization and Numerical mathematics	Z,ZK	5
Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.			
QNIE-AVM	Adiabatic computing and variational methods	Z,ZK	6
The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA.			
NIE-KRY	Advanced Cryptology	Z,ZK	5
Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions.			
NIE-AOS	Advanced Operating Systems	Z,ZK	5
The course focuses on system programming in Unix-like operating systems, with an emphasis on OS kernel development and advanced technologies for Unix system administration. Students will learn about the architecture and data structures of the OS kernel, process and memory management, the internal architecture of modern file systems, implementations of device control and network communication methods, kernel and OS booting techniques, as well as kernel debugging using dynamic instrumentation. They will also gain knowledge of kernel development and modification processes, ensuring kernel portability, and the use of containerization and virtualization technologies. Additionally, students will become familiar with the specifics of kernel implementation for embedded systems and real-time systems. Theoretical and general principles will be demonstrated primarily using the Linux kernel. The tutorials will focus on developing Linux kernel modules and using tools for managing the discussed technologies.			
NIE-APT	Advanced Program Testing	Z,ZK	5
Testing a program is essential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The goal of the course is to present advanced program testing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.			
NIE-AIB	Algorithms of Information Security	Z,ZK	5
Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems.			
FIT-BIP	Blended Intensive Programme	Z	3
NIE-BLO	Blockchain	Z,ZK	5
Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.			
NIE-GEN	Code Generators	Z,ZK	5
Advanced techniques of translating programs written in high-level programming languages are essential for understanding the field of systems programming. This primarily involves understanding the algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems programming. Students will become familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages.			
NIE-CPX.26	Complexity Theory	Z,ZK	6
Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.			
NIE-KOD	Data Compression	Z,ZK	5
Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data compression methods being used in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students learn the fundamentals of lossy data compression methods used in image, audio, and video compression.			
NIE-DSS	Decision Support Systems	Z,ZK	5
The aim of the course is to provide students with knowledge and skills in decision support systems, their classification (Powerova), selected principles of data-oriented, model-oriented and knowledge-oriented decision support systems. Students will also gain knowledge of multicriterial decision-making methods and game theory. They will also learn about the principles of conceptually and ontologically oriented decision support systems and the basics of distribution, optimization and evolution methods and algorithms.			
FITE-DIF	Differential equations	Z,ZK	5
This course provides a foundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essential solution methods like separation of variables. Key theorems on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered with methods like characteristic polynomial analysis, followed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applications. Finally, an introduction to partial differential equations (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving ODEs and PDEs, including implicit and explicit Euler methods, Runge-Kutta methods, and finite element methods for both ODEs and PDEs.			
ANIE-SIM	Digital Circuit Simulation and Verification	Z,ZK	5
The aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers recent verification methods, too.			
NIE-DSV	Distributed Systems and Computing	Z,ZK	5
Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures.			
NIE-EPC	Effective C++ programming	Z,ZK	5
Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements.			
NIE-EVY	Efficient Text Pattern Matching	Z,ZK	5
Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching.			

ANIE-EHW	Embedded Hardware	Z,ZK	5
The course provides a comprehensive overview of fundamental techniques and theoretical principles underlying the design of digital systems at both small and large scales. It establishes the conceptual and practical foundation for the development of advanced embedded systems that exploit functional specialization to achieve efficient hardware implementations and computational acceleration. Topics include high-speed system design methodologies, standard internal communication protocols, and the utilization of inherent computational parallelism within specialized hardware structures and system architectures.			
ANIE-BVS	Embedded Security	Z,ZK	5
Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems.			
ANIE-ESW	Embedded Software	Z,ZK	5
The course introduces students to the principles and distinctive features of software development for embedded systems. It leads students from the basics of programming in C and code optimization through key topics such as reliable software design, embedded operating systems, and signal processing, culminating in advanced methods that integrate embedded software development with artificial intelligence.			
ANIE-BKO	Error Control Coding	Z,ZK	5
The course extends the basic knowledge of error-control codes used in modern systems for error detection and correction. It presents the necessary mathematical theory and the principles of linear and cyclic codes, as well as codes for correcting multiple errors, burst errors, and whole symbols (bytes). Students will also learn how to implement these detection and correction techniques for different types of transmission (parallel and serial), when storing data in memories and when transmitting it over telecommunication channels.			
QNIE-VOT	Fiber Optic Technology	Z,ZK	6
The aim of the course is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of optical measurement techniques and measurement methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of optical communication systems - connectors, couplers, coupling elements, refractive indices.			
NIE-GPU	GPU Architectures and Programming	Z,ZK	5
Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems.			
NIE-GAK.26	Graph theory and combinatorics	Z,ZK	6
The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms. The emphasis will be not only on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topics from graph and hypergraph coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory will be also applied in the fields of combinatorics on words, formal languages and bioinformatics.			
NIE-HWB	Hardware Security	Z,ZK	5
The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer.			
FITE-EHD	Introduction to European Economic History	Z,ZK	3
The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion.			
NIE-LOM	Linear Optimization and Methods	Z,ZK	5
Students will gain an overview of applications of optimization methods in computer science, economics and industrial practice. They will be introduced to the practical importance of linear and integer programming. They will be able to work with optimization software and to master the languages used in its programming. They will be able to formalise optimisation problems in the areas of computer science (e.g. task allocation to processors, network flow analysis), resource distribution and allocation (traffic problems, business traveller problem, etc.). Gain an overview of computational complexity issues in optimization. Gain a good understanding of linear programming algorithms and selected integer linear programming algorithms.			
ANIE-MLM	Machine Learning Methods	Z,ZK	5
The course introduces students to machine learning methods applicable within their specializations in the follow-up Applied Informatics program. These principles and competencies are not part of the common undergraduate curriculum and are typically taught only in specializations focused on artificial intelligence. The aim is to understand the theoretical foundations and to gain practical experience in applying models suitable for regression and classification tasks within supervised learning, including kernel methods and neural networks. In unsupervised learning, students will become familiar primarily with clustering models and principal component analysis. The course also covers model evaluation techniques and fundamental methods for data preprocessing. Practical exercises involve data analysis and model implementation using the Python libraries pandas, scikit-learn, and PyTorch.			
NIE-MKY.26	Mathematics for Cryptology	Z,ZK	7
Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices.			
NIE-MPS	Modern Computer Networks	Z,ZK	5
The course is divided into two complementary parts modern network technologies and computer network security. The first part is devoted to explaining the principles of modern network technologies and communication protocols that enable high throughput, low latency, and fault tolerance. The lectures also cover the principles of modern software-defined networks, which are gradually replacing traditional networks. The first part concludes with an explanation of protocols and technologies designed for real-time video and voice transmission. In the second part, the basic principles and technologies that support and enhance computer network security are introduced. Subsequent lectures focus on explaining the principles of well-known network attacks in local area networks and on the Internet. Finally, modern systems for detecting and mitigating network attacks are presented, including systems for sharing information that make it possible to prevent network attacks proactively. Students gain hands-on experience with these concepts in the network laboratory.			
NIE-MCC	Multicore CPU Computing	Z,ZK	5
Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications.			
ANIE-COM	Network Communication	Z,ZK	5
The course focuses on the technical aspects of communication between devices and systems. During the semester, topics will be presented ranging from physical layers and communication media to communication protocols and traffic monitoring. Upon completion, students will gain an understanding of the technical limitations and capabilities of communication tools that can be applied in the design and development of real hardware or software systems.			

NIE-SIB	Network Security	Z,ZK	5
The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response).			
QNIE-OPM	Optical measurements	Z,ZK	6
The aim of this course is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaches, through the use of fiber optics in areas where it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intelligent transport infrastructures, to macroscopic sensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an understanding of the physical mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reconstruction.			
NIE-PAM	Parameterized Algorithms	Z,ZK	4
There are many optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necessary to solve these problems exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one can find a common property (parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponentially in this (small) parameter and polynomially in the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial time preprocessing of the input, which is not possible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution method. We will present a plethora of parameterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (presumably) does not exist. We will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes.			
NIE-SYP	Parsing and Compilers	Z,ZK	5
The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing.			
NIE-PML	Personalized Machine Learning	Z,ZK	5
Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities.			
NIE-PDL	Practical Deep Learning	KZ	5
This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing.			
FIT-PMA	Programming in Mathematica	Z,ZK	4
Students will be working with modern technical and scientific software. Students will learn how to use different programming styles (functional programming, rule-based programming, etc.), how to create dynamic interactive applications and visualisations, data processing and presentations.			
QNIE-KOS	Quantum Optical Communications and Networks	Z,ZK	6
The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics.			
NIE-REV	Reverse Engineering	Z,ZK	5
Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C ++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction.			
NIE-RUN	Runtime Systems	Z,ZK	5
As the abstraction level of programming languages steadily rises, modern programs require greater and greater support during their runtime. This course introduces students to various aspects of the runtime support, such as runtime-effective program description, memory management support and garbage collection, just-in-time compilation, and interoperability with other languages and systems.			
NIE-APR	Selected Methods for Program Analysis	Z,ZK	5
This course introduces you to program analysisthe automated reasoning about the behavior of computer programs. We will cover both static and dynamic analysis. In static analysis, we explore the art of reasoning about programs without executing them, including techniques for program understanding, optimization, and error detection. In dynamic analysis, we examine individual program executions within specific environments and inputs.			
NIE-SEM	Semantics of Programming Languages	Z,ZK	5
The aim of the course is to introduce students to the basics of programming language semantics, which forms the foundation for the study and implementation of programming languages. These techniques are also important for program verification, the implementation of optimizations, and the general design of programming languages. The emphasis will be on comparing operational and denotational semantics. The techniques used are also applicable when analysing languages specified only by an operational semantics. The course will enable students to acquire the skills needed to implement language constructs, regardless of whether their description comes from theoretical or engineering sources in the literature.			
NIE-SBF	System Security and Forensics	Z,ZK	5
Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).			
ANIE-TSP	Testing and Reliability	Z,ZK	5
Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits.			
NIE-VCC	Virtualization and Cloud Computing	Z,ZK	5
Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development).			

FITE-SEP	World Economy and Business	Z,ZK	4

The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite.

List of courses of this pass:

Code	Name of the course	Completion	Credits
ANIE-BKO	Error Control Coding	Z,ZK	5
The course extends the basic knowledge of error-control codes used in modern systems for error detection and correction. It presents the necessary mathematical theory and the principles of linear and cyclic codes, as well as codes for correcting multiple errors, burst errors, and whole symbols (bytes). Students will also learn how to implement these detection and correction techniques for different types of transmission (parallel and serial), when storing data in memories and when transmitting it over telecommunication channels.			
ANIE-BVS	Embedded Security	Z,ZK	5
Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems.			
ANIE-COM	Network Communication	Z,ZK	5
The course focuses on the technical aspects of communication between devices and systems. During the semester, topics will be presented ranging from physical layers and communication media to communication protocols and traffic monitoring. Upon completion, students will gain an understanding of the technical limitations and capabilities of communication tools that can be applied in the design and development of real hardware or software systems.			
ANIE-EHW	Embedded Hardware	Z,ZK	5
The course provides a comprehensive overview of fundamental techniques and theoretical principles underlying the design of digital systems at both small and large scales. It establishes the conceptual and practical foundation for the development of advanced embedded systems that exploit functional specialization to achieve efficient hardware implementations and computational acceleration. Topics include high-speed system design methodologies, standard internal communication protocols, and the utilization of inherent computational parallelism within specialized hardware structures and system architectures.			
ANIE-ESW	Embedded Software	Z,ZK	5
The course introduces students to the principles and distinctive features of software development for embedded systems. It leads students from the basics of programming in C and code optimization through key topics such as reliable software design, embedded operating systems, and signal processing, culminating in advanced methods that integrate embedded software development with artificial intelligence.			
ANIE-MLM	Machine Learning Methods	Z,ZK	5
The course introduces students to machine learning methods applicable within their specializations in the follow-up Applied Informatics program. These principles and competencies are not part of the common undergraduate curriculum and are typically taught only in specializations focused on artificial intelligence. The aim is to understand the theoretical foundations and to gain practical experience in applying models suitable for regression and classification tasks within supervised learning, including kernel methods and neural networks. In unsupervised learning, students will become familiar primarily with clustering models and principal component analysis. The course also covers model evaluation techniques and fundamental methods for data preprocessing. Practical exercises involve data analysis and model implementation using the Python libraries pandas, scikit-learn, and PyTorch.			
ANIE-SIM	Digital Circuit Simulation and Verification	Z,ZK	5
The aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers recent verification methods, too.			
ANIE-TSP	Testing and Reliability	Z,ZK	5
Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits.			
BQM32KOS	Quantum optical communications and networks	Z,ZK	6
TThe goal of this course is to provide a comprehensive engineering insight into optical communications, with a specific focus on Quantum Key Distribution (QKD). The subject breaks down boundaries between traditional disciplines, integrating knowledge of wave optics, hardware architecture, and network security. Students will learn to perceive the communication system as a holistic entity, where the physical layer directly defines the limits and capabilities of digital security. The course prepares students for the real-world challenges associated with deploying quantum technologies into existing telecommunications infrastructure.			
BQM36AVM	Adiabatic computing and variational methods	Z,ZK	6
BQM36KPB	Quantum computing in banking	Z,ZK	5
BQM36QTC	Quantum (State, Process, Channel) Tomography and Quantum Optimal Control	Z,ZK	6
FIT-BIP	Blended Intensive Programme	Z	3
FIT-PMA	Programming in Mathematica	Z,ZK	4
Students will be working with modern technical and scientific software. Students will learn how to use different programming styles (functional programming, rule-based programming, etc.), how to create dynamic interactive applications and visualisations, data processing and presentations.			
FITE-DIF	Differential equations	Z,ZK	5
This course provides a foundational overview of differential equations, starting with basic motivation and examples of ODEs and progressing to essential solution methods like separation of variables. Key theorems on existence and uniqueness establish when solutions can be guaranteed. Linear and system-based ODEs are covered with methods like characteristic polynomial analysis, followed by examples of non-linear models such as predator-prey and epidemiological models to showcase real-world applications. Finally, an introduction to partial differential equations (PDEs) extends these concepts to multi-variable contexts. The course will also cover numerical methods for solving ODEs and PDEs, including implicit and explicit Euler methods, Runge-Kutta methods, and finite element methods for both ODEs and PDEs.			
FITE-EHD	Introduction to European Economic History	Z,ZK	3
The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion.			

<table>
<tr><td>FITE-SEP</td><td>World Economy and Business</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="4">The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite.</td></tr>
<tr><td>NIE-AIB</td><td>Algorithms of Information Security</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems.</td></tr>
<tr><td>NIE-AOS</td><td>Advanced Operating Systems</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The course focuses on system programming in Unix-like operating systems, with an emphasis on OS kernel development and advanced technologies for Unix system administration. Students will learn about the architecture and data structures of the OS kernel, process and memory management, the internal architecture of modern file systems, implementations of device control and network communication methods, kernel and OS booting techniques, as well as kernel debugging using dynamic instrumentation. They will also gain knowledge of kernel development and modification processes, ensuring kernel portability, and the use of containerization and virtualization technologies. Additionally, students will become familiar with the specifics of kernel implementation for embedded systems and real-time systems. Theoretical and general principles will be demonstrated primarily using the Linux kernel. The tutorials will focus on developing Linux kernel modules and using tools for managing the discussed technologies.</td></tr>
<tr><td>NIE-APR</td><td>Selected Methods for Program Analysis</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">This course introduces you to program analysisthe automated reasoning about the behavior of computer programs. We will cover both static and dynamic analysis. In static analysis, we explore the art of reasoning about programs without executing them, including techniques for program understanding, optimization, and error detection. In dynamic analysis, we examine individual program executions within specific environments and inputs.</td></tr>
<tr><td>NIE-APT</td><td>Advanced Program Testing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Testing a program is essential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The goal of the course is to present advanced program testing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.</td></tr>
<tr><td>NIE-BLO</td><td>Blockchain</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business.</td></tr>
<tr><td>NIE-CPX.26</td><td>Complexity Theory</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.</td></tr>
<tr><td>NIE-DSS</td><td>Decision Support Systems</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The aim of the course is to provide students with knowledge and skills in decision support systems, their classification (Powerova), selected principles of data-oriented, model-oriented and knowledge-oriented decision support systems. Students will also gain knowledge of multicriterial decision-making methods and game theory. They will also learn about the principles of conceptually and ontologically oriented decision support systems and the basics of distribution, optimization and evolution methods and algorithms.</td></tr>
<tr><td>NIE-DSV</td><td>Distributed Systems and Computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students are introduced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing processes and communication channels. They learn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that support high availability of both data and services, and safety in case of failures.</td></tr>
<tr><td>NIE-EPC</td><td>Effective C++ programming</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students learn how to use the modern features of contemporary versions of the C++ programming language for software development. The course focuses on programming effectivity and efficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor time requirements.</td></tr>
<tr><td>NIE-EVY</td><td>Efficient Text Pattern Matching</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching.</td></tr>
<tr><td>NIE-GAK.26</td><td>Graph theory and combinatorics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms. The emphasis will be not only on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topics from graph and hypergraph coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory will be also applied in the fields of combinatorics on words, formal languages and bioinformatics.</td></tr>
<tr><td>NIE-GEN</td><td>Code Generators</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Advanced techniques of translating programs written in high-level programming languages are essential for understanding the field of systems programming. This primarily involves understanding the algorithms and techniques used to translate more complex programming constructs of modern languages employed in systems programming. Students will become familiar with both the theoretical and practical aspects of implementing the back-end of optimizing compilers for programming languages.</td></tr>
<tr><td>NIE-GPU</td><td>GPU Architectures and Programming</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems.</td></tr>
<tr><td>NIE-HWB</td><td>Hardware Security</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer.</td></tr>
<tr><td>NIE-KOD</td><td>Data Compression</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data compression methods being used in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students learn the fundamentals of lossy data compression methods used in image, audio, and video compression.</td></tr>
<tr><td>NIE-KRY</td><td>Advanced Cryptology</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions.</td></tr>
</table>

<table>
<tr><td>NIE-LOM</td><td>Linear Optimization and Methods</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will gain an overview of applications of optimization methods in computer science, economics and industrial practice. They will be introduced to the practical importance of linear and integer programming. They will be able to work with optimization software and to master the languages used in its programming. They will be able to formalise optimisation problems in the areas of computer science (e.g. task allocation to processors, network flow analysis), resource distribution and allocation (traffic problems, business traveller problem, etc.). Gain an overview of computational complexity issues in optimization. Gain a good understanding of linear programming algorithms and selected integer linear programming algorithms.</td></tr>
<tr><td>NIE-MCC</td><td>Multicore CPU Computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications.</td></tr>
<tr><td>NIE-MKY.26</td><td>Mathematics for Cryptology</td><td>Z,ZK</td><td>7</td></tr>
<tr><td colspan="4">Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices.</td></tr>
<tr><td>NIE-MPS</td><td>Modern Computer Networks</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The course is divided into two complementary parts modern network technologies and computer network security. The first part is devoted to explaining the principles of modern network technologies and communication protocols that enable high throughput, low latency, and fault tolerance. The lectures also cover the principles of modern software-defined networks, which are gradually replacing traditional networks. The first part concludes with an explanation of protocols and technologies designed for real-time video and voice transmission. In the second part, the basic principles and technologies that support and enhance computer network security are introduced. Subsequent lectures focus on explaining the principles of well-known network attacks in local area networks and on the Internet. Finally, modern systems for detecting and mitigating network attacks are presented, including systems for sharing information that make it possible to prevent network attacks proactively. Students gain hands-on experience with these concepts in the network laboratory.</td></tr>
<tr><td>NIE-PAM</td><td>Parameterized Algorithms</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="4">There are many optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necessary to solve these problems exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one can find a common property (parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponentially in this (small) parameter and polynomially in the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial time preprocessing of the input, which is not possible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution method. We will present a plethora of parameterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (presumably) does not exist. We will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes.</td></tr>
<tr><td>NIE-PDL</td><td>Practical Deep Learning</td><td>KZ</td><td>5</td></tr>
<tr><td colspan="4">This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing.</td></tr>
<tr><td>NIE-PML</td><td>Personalized Machine Learning</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities.</td></tr>
<tr><td>NIE-REV</td><td>Reverse Engineering</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C ++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction.</td></tr>
<tr><td>NIE-RUN</td><td>Runtime Systems</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">As the abstraction level of programming languages steadily rises, modern programs require greater and greater support during their runtime. This course introduces students to various aspects of the runtime support, such as runtime-effective program description, memory management support and garbage collection, just-in-time compilation, and interoperability with other languages and systems.</td></tr>
<tr><td>NIE-SBF</td><td>System Security and Forensics</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).</td></tr>
<tr><td>NIE-SEM</td><td>Semantics of Programming Languages</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The aim of the course is to introduce students to the basics of programming language semantics, which forms the foundation for the study and implementation of programming languages. These techniques are also important for program verification, the implementation of optimizations, and the general design of programming languages. The emphasis will be on comparing operational and denotational semantics. The techniques used are also applicable when analysing languages specified only by an operational semantics. The course will enable students to acquire the skills needed to implement language constructs, regardless of whether their description comes from theoretical or engineering sources in the literature.</td></tr>
<tr><td>NIE-SIB</td><td>Network Security</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response).</td></tr>
<tr><td>NIE-SYP</td><td>Parsing and Compilers</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing.</td></tr>
<tr><td>NIE-VCC</td><td>Virtualization and Cloud Computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development).</td></tr>
</table>

<table>
<tr><td>QNIE-AVM</td><td>Adiabatic computing and variational methods</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA.</td></tr>
<tr><td>QNIE-CPX</td><td>Complexity Theory</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems.</td></tr>
<tr><td>QNIE-DIP</td><td>Diploma Thesis</td><td>Z</td><td>30</td></tr>
<tr><td colspan="4">Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile.</td></tr>
<tr><td>QNIE-KKP</td><td>Cryptology and Quantum Computing</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last lectures deal with cryptosystems using quantum phenomena.</td></tr>
<tr><td>QNIE-KOS</td><td>Quantum Optical Communications and Networks</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics.</td></tr>
<tr><td>QNIE-LOM</td><td>Linear Optimization and Methods</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will gain an overview of applications of optimization methods in computer science, economics and industrial practice. They will be introduced to the practical importance of linear and integer programming. They will be able to work with optimization software and to master the languages used in its programming. They will be able to formalise optimisation problems in the areas of computer science (e.g. task allocation to processors, network flow analysis), resource distribution and allocation (traffic problems, business traveller problem, etc.). Gain an overview of computational complexity issues in optimization. Gain a good understanding of linear programming algorithms and selected integer linear programming algorithms.</td></tr>
<tr><td>QNIE-MPR</td><td>Master Project</td><td>Z</td><td>7</td></tr>
<tr><td colspan="4">1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester.</td></tr>
<tr><td>QNIE-MQI</td><td>Mathematics for Quantum Informatics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization, diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform.</td></tr>
<tr><td>QNIE-NMK</td><td>Numerical methods for quantum computation</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.</td></tr>
<tr><td>QNIE-OPM</td><td>Optical measurements</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The aim of this course is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaches, through the use of fiber optics in areas where it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intelligent transport infrastructures, to macroscopic sensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an understanding of the physical mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reconstruction.</td></tr>
<tr><td>QNIE-OQC</td><td>Optical quantum computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.</td></tr>
<tr><td>QNIE-OVV</td><td>Optimization for Scientific Computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.</td></tr>
<tr><td>QNIE-PJK</td><td>Programming languages for quantum computing</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper).). In the seminars the student will learn the basics of programming in the higher programming language Silq.</td></tr>
<tr><td>QNIE-PNM</td><td>Parallelization of numerical methods</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.</td></tr>
<tr><td>QNIE-PON</td><td>Selected Topics in Optimization and Numerical mathematics</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.</td></tr>
<tr><td>QNIE-PPS</td><td>Programming of parallel systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Nowadays, multi-core processors and GPU accelerators have become common components of computing clusters and high-performance computing systems, so knowledge and skills related to parallel programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming methods of parallel computers with shared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to combine parallelization techniques</td></tr>
</table>

<table>
<tr><td colspan="4">at all three levels. Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundamental parallel algorithms and be able to analyze the limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In addition to the necessary theory in lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments.</td></tr>
<tr><td>QNIE-QC1</td><td>Quantum Computation 1</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course introduces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum computation uses quantum circuits, which will be demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its visualization, measurements, basic gates and their composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the properties of quantum states. The course will also cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estimation algorithm, and the Shor algorithm.</td></tr>
<tr><td>QNIE-QC2</td><td>Quantum Computing 2</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Quantum Computing 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algorithms solving linear algebra problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error correction.</td></tr>
<tr><td>QNIE-QEC</td><td>Quantum error correction</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized, atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.</td></tr>
<tr><td>QNIE-QML</td><td>Quantum machine learning</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.</td></tr>
<tr><td>QNIE-QOM</td><td>Quantum Optics, Metrology, Sensing and Imaging</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.</td></tr>
<tr><td>QNIE-TIN</td><td>Information Theory</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course focuses on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The coding problem is addressed probabilistically, the relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case of the noisy channel we focus on the set of typical sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as conditional distributions, goodness-of-fit and independence tests, and an introduction to random chains.</td></tr>
<tr><td>QNIE-UKT</td><td>Introduction to Quantum Theory</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode of a quantized electromagnetic field.</td></tr>
<tr><td>QNIE-VOT</td><td>Fiber Optic Technology</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The aim of the course is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of optical measurement techniques and measurement methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of optical communication systems - connectors, couplers, coupling elements, refractive indices.</td></tr>
</table>

For updated information see http://bilakniha.cvut.cz/en/FF.html
Generated: day 2026-05-11, time 20:15.