Study plan

Name of study plan: Matematická fyzika

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department: Welcome page
Garantor of the study branch:
Program of study: Mathematical Physics
Type of study: Follow-up master full-time
Required credits: 0
Elective courses credits: 120
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: 0
The role of the block: P

Code of the group: NMSPMF1
Name of the group: MDP P_MFN 1st year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 9 courses
Credits in the group: 0
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
02GMF2	**Geometric Methods in Physics 2** *Jan Vysoký* ***Jan Vysoký*** *Libor Šnobl (Gar.)*	Z,ZK	5	2+2	L	P
02GR	**Groups and Representations** *Goce Chadzitaskos, Lenka Motlochová* ***Lenka Motlochová*** *Goce Chadzitaskos (Gar.)*	Z,ZK	3	2+1	Z	P
02KFA	**Quantum Physics** *Michal Jex* ***Michal Jex*** *Igor Jex (Gar.)*	Z,ZK	6	4P+2C	L	P
02KTPA1	**Quantum Field Theory 1** *Václav Zatloukal* ***Václav Zatloukal*** *Martin Štefaňák (Gar.)*	Z,ZK	8	4P+2C	Z	P
02KTPA2	**Quantum Field Theory 2** *Petr Jizba* ***Václav Zatloukal*** *Martin Štefaňák (Gar.)*	Z,ZK	8	4P+2C	L	P
02LAG	**Lie Algebras and Lie Groups** *Libor Šnobl* ***Martin Štefaňák*** *Libor Šnobl (Gar.)*	Z,ZK	7	4P+2C	Z	P
02VUMF1	**Research Project 1** ***Jan Vysoký*** *Libor Šnobl (Gar.)*	Z	6	6	Z,L	P
02VUMF2	**Research Project 2** *Jan Vysoký, Libor Šnobl, Václav Zatloukal, Martin Štefaňák, Petr Jizba, Josef Schmidt, David Krejčiřík, Matěj Tušek, Jiří Tolar* ***Aurél Gábor Gábris*** *Libor Šnobl (Gar.)*	KZ	8	8	L,Z	P
02ZS	**Winter School of Mathematical Physics** ***Jiří Hrivnák*** *Jiří Hrivnák (Gar.)*	Z	1	1týd.	Z	P

Characteristics of the courses of this group of Study Plan: Code=NMSPMF1 Name=MDP P_MFN 1st year

02GMF2	Geometric Methods in Physics 2	Z,ZK	5

A theory of gauge fields forms the foundation of contemporary particle physics, namely of the Standard Model. The main goal of this course to to acquaint students with the mathematical apparatus required for its geometric description. We will focus on theory of principal fiber bundles and the interpretation of gauge fields as connection forms on principal fiber bundles. All theoretical concepts are demonstrated on particular examples, e.g. frame bundle, Hopf fibration and Yang-Mills field.

02GR	Groups and Representations	Z,ZK	3

The aim of the lectures is to acquaint students with the basic concepts of discrete group theory and their representations. The student will be thoroughly acquainted with the methods of classification of finite groups, decomposition of groups into direct and semidirect products, and with the properties of reducible and irreducible representations.

02KFA	Quantum Physics	Z,ZK	6

The goal of the lecture is formulating and developing quantum theory as a physically motivated, but mathematically rigorous theory built upon the analysis of bounded and unbounded linear operators on separable Hilbert spaces. Previous knowledge of quantum mechanics is an advantage but not a predisposition for the course. The pivot point is the establishing of the main postulates of the theory and deriving their consequences for model systems, as well as a detailed study of the most commonly used observables in quantum mechanics. The lecture focuses on the exactness and proofs of the statements. Some common mistakes resulting from breaking the assumptions of these are also discussed.

02KTPA1	Quantum Field Theory 1	Z,ZK	8
The lecture aims to introduce the students to both fundamental and applied parts of quantum field theory. The focus is in particular on equations of relativistic quantum mechanics, canonical quantization of scalar and bispinor field, perturbation theory (Feynmans rules) and basics of renormalization. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity.			
02KTPA2	Quantum Field Theory 2	Z,ZK	8
The lecture aims at introducing the students to the Feynmans functional integral and its applications. The focus is on broadening the knowledge of modern parts of relativistic and non-relativistic quantum field theory and statistical physics. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity.			
02LAG	Lie Algebras and Lie Groups	Z,ZK	7
The aim of the lectures is get students familiar with the basic concepts of the theory of Lie groups and Lie algebras, and their finite-dimensional representations. The students will also learn Cartan's classification of simple complex Lie algebras, which is the fundamental result in this field of mathematics, including its derivation. Emphasis is put on detailed investigation of explicit examples of the introduced mathematical structures and their applications.			
02VUMF1	Research Project 1	Z	6
The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02VUMF2	Research Project 2	KZ	8
The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02ZS	Winter School of Mathematical Physics	Z	1
The aim of the winter school of mathematical physics is to significantly improve presentation skills of the students and their ability to follow specialized conference presentations in English. Each student presents a specialized talk in English on the topic of his/her own research. The goal is to create such suitable conditions that motivate students towards a rigorous formulation of their own research together with high quality specialized presentation and abstract. The scientific level of the student presentations is guaranteed by audience comprising experts from CTU and other universities.			

Code of the group: NMSPMF2
Name of the group: MDP P_MFN 2nd year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 5 courses
Credits in the group: 0
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
02ALT	**Algebraic Topology** *Jan Vysoký* ***Jan Vysoký*** *Jan Vysoký (Gar.)*	Z,ZK	4	2P+2C	Z	P
02DPMF1	**Master Thesis 1** ***David Krejčiřík*** *Libor Šnobl (Gar.)*	Z	10	10	Z,L	P
02DPMF2	**Master Thesis 2** ***David Krejčiřík*** *Libor Šnobl (Gar.)*	Z	20	20	L,Z	P
02DSMF	**Diploma Seminar** ***Jiří Hrivnák*** *Jiří Hrivnák (Gar.)*	Z	1	0P+2C	L	P
02VPSFA	**Selected Topics in Statistical Physics and Thermodynamics** *Igor Jex* ***Martin Štefaňák*** *Igor Jex (Gar.)*	Z,ZK	7	4P+2C	Z	P

Characteristics of the courses of this group of Study Plan: Code=NMSPMF2 Name=MDP P_MFN 2nd year

02ALT	Algebraic Topology	Z,ZK	4
A study of modern mathematical and theoretical physics requires one to acquire an ever increasing knowledge of mathematical apparautus. The main goal of this course is to acquaint students with basic methods used in algebraic topology, namely elements of category theory, homototopies, homological algebra and cohomology. An important objective is to enhance the mathematical language by concepts appearing universally across disciplines like differential geometry and abstract algebra. During excercise sessions, students will try practical calculations of introduced mathematical structures.			
02DPMF1	Master Thesis 1	Z	10
The diploma project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02DPMF2	Master Thesis 2	Z	20
The diploma project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02DSMF	Diploma Seminar	Z	1
In the first part of the seminar, students familiarize themselves with the general principles of publishing and presenting scientific work and the formal requirements for diploma projects at the faculty. The second part is designed as a practical training for the defence of the diploma project. The students give oral presentations of the current state of the research results achieved during the work on their projects. Each presentation is followed by a discussion on scientific matters as well as on the possibilities of improving the students performance.			
02VPSFA	Selected Topics in Statistical Physics and Thermodynamics	Z,ZK	7
The course concentrates on some advanced topics of statistical mechanics not discussed in the basic course on thermodynamics and statistical physics. Question concerning density matrices, the behaviours of nonideal gases and its macroscopic description, microscopic description of phase transitions, the role of fluctuations are addressed in detail.			

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

Code of the group: NMSPMFV
Name of the group: MDP P_MFN Optional courses
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
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
01ASY	**Asymptotical Methods** *Jiří Mikyška **Jiří Mikyška** Jiří Mikyška (Gar.)*	Z,ZK	3	2+1	Z	v
02COX	**Coxeter Groups** *Jiří Hrivnák **Jiří Hrivnák** Jiří Hrivnák (Gar.)*	Z	2	2+0		v
01FAN3	**Functional Analysis 3** *Pavel Šťovíček **Pavel Šťovíček** Pavel Šťovíček (Gar.)*	Z,ZK	5	2P+2C	Z	v
02FG	**Physics of graphene described by Dirac equation** *Vít Jakubský **Vít Jakubský** Vít Jakubský (Gar.)*	Z	2	2P+0C	L	v
01SPEC	**Geometrical Aspects of Spectral Theory** *David Krejčiřík **David Krejčiřík** David Krejčiřík (Gar.)*	ZK	2	2+0	L	v
02GSKS	**Groups of symmetry of quantum systems** *Jiří Tolar **Martin Štefaňák** Jiří Tolar (Gar.)*	ZK	2	26P	Z	v
02INB	**Integrability and beyond** *Libor Šnobl, Antonella Marchesiello **Libor Šnobl** Libor Šnobl (Gar.)*	Z	2	2P+0C		v
02KCH	**Quantum Chemistry** *Michal Jex **Michal Jex** Michal Jex (Gar.)*	Z,ZK	3	2P+1C	Z	v
02QIC	**Quantum Information and Communication** *Aurél Gábor Gábris **Aurél Gábor Gábris** Martin Štefaňák (Gar.)*	Z,ZK	4	3P+1C	Z	v
02KO1	**Quantum Optics 1** *Václav Potoček **Václav Potoček** Igor Jex (Gar.)*	Z,ZK	4	2P+2C	Z	v
02KO2	**Quantum Optics 2** *Václav Potoček **Václav Potoček** Igor Jex (Gar.)*	Z,ZK	4	2P+2C	L	v
01KVGR1	**Quantum Groups 1** ***Čestmír Burdík** Čestmír Burdík (Gar.)*	Z	2	2+0	Z	v
02KVK1	**Quantum Circle 1** ***Martin Štefaňák** Pavel Exner (Gar.)*	Z	2	0+2	Z	v
02KVK2	**Quantum Circle 2** ***Martin Štefaňák** Pavel Exner (Gar.)*	Z	2	0+2	L	v
01MMNS	**Mathematical Modelling of Non-linear Systems** *Michal Beneš **Michal Beneš** Michal Beneš (Gar.)*	ZK	3	1P+1C	Z	v
02NGR	**Numerical Relativity** *Josef Schmidt **Josef Schmidt** Josef Schmidt (Gar.)*	ZK	2	2P+0C	L	v
02OKS	**Open Quantum Systems** *Jaroslav Novotný **Martin Štefaňák** Jaroslav Novotný (Gar.)*	Z	2	2+0		v
02PPKT	**Advanced Topics of Quantum Theory** *Pavel Exner **Martin Štefaňák** Pavel Exner (Gar.)*	ZK	2	2+0	L	v
02QPRGA	**Quantum Programming** *Aurél Gábor Gábris, Iskender Yalcinkaya **Aurél Gábor Gábris** Aurél Gábor Gábris (Gar.)*	Z	3	1P+1C	L	v
02REL1	**Relativistic Physics I** *Oldřich Semerák **Martin Štefaňák***	Z,ZK	6	4+2	Z	v
02REL2	**Relativistic Physics 2** *Oldřich Semerák **Martin Štefaňák** Oldřich Semerák (Gar.)*	Z,ZK	6	4+2	L	v
02RMMF	**Solvable Models of Mathematical Physics** *Ladislav Hlavatý **Martin Štefaňák** Ladislav Hlavatý (Gar.)*	Z	2	2+0	L	v
02SKTPE1	**Seminar on quantum field theory 1** *Petr Jizba **Petr Jizba** Petr Jizba (Gar.)*	Z	3	2P+1C	Z	v
02SKTPE2	**Seminar on quantum field theory 2** *Petr Jizba **Václav Zatloukal** Petr Jizba (Gar.)*	Z	3	2P+1C	L	v
01TG	**Graph Theory** *Jan Volec, Petr Ambrož **Petr Ambrož** Petr Ambrož (Gar.)*	ZK	5	4P+0C		v
01NAH	**Theory of Random Processes** *Jan Vybíral **Jan Vybíral** Jan Vybíral (Gar.)*	ZK	3	3+0	Z	v
02UST1	**Introduction to Strings 1** *Jan Vysoký, Ladislav Hlavatý **Jan Vysoký** Ladislav Hlavatý (Gar.)*	Z	3	2+1	Z	v
02UST2	**Introduction to Strings 2** *Jan Vysoký, Ladislav Hlavatý **Jan Vysoký** Ladislav Hlavatý (Gar.)*	Z	3	2+1	L	v
01VAM	**Variational Methods** *Michal Beneš **Michal Beneš** Michal Beneš (Gar.)*	ZK	3	1P+1C	Z	v

Characteristics of the courses of this group of Study Plan: Code=NMSPMFV Name=MDP P_MFN Optional courses

01ASY	Asymptotical Methods	Z,ZK	3
Examples. Addition parts of mathematical analysis (generalized Lebesgue integral, parametric integrals.) Asymptotic relations a expansions - properties; algebraical and analytical operations. Applied asymptotics of sequences and sums; integrals of Laplace and Fourier type.			

02COX	Coxeter Groups	Z	2	The course is an introduction to the theory of Coxeter groups and their invariant theory. The case of the finite Coxeter groups - the reflection groups and their properties are studied. The notions of the Weyl chamber and length are defined. General theory of the Coxeter groups, the corresponding bilinear forms and the theory of their classification represent abstract generalization of the reflection groups. The study of affine Weyl groups and related objects forms basic example of infinite Coxeter groups. As an introduction to the invariant theory the MacDonald identity and the Weyl identity are presented.
01FAN3	Functional Analysis 3	Z,ZK	5	Advanced parts of functional analysis needed for theory of representations of Lie groups and quantum theory. Compact operators, their ideals, unbounded selfadjoint operators, theory of selfadjoint extension of symmetric operators, Stones theorem, quadratic forms and Bochner integral. The basics of Banach algebras and C*-algebras.
02FG	Physics of graphene described by Dirac equation	Z	2	General description of crystal. Tight-binding model of graphene and its approximation in terms of Dirac equation.Transport of Dirac fermions in graphene in presence of external fields and related phenomena. Bilayer graphene, its description and properties in the external magnetic field. Carbon nanotubes, their classification. Basic description of graphene nanoribbons,boundary conditions and energy. Dirac fermions in curved space, fullerenes. Other Dirac materials.
01SPEC	Geometrical Aspects of Spectral Theory	ZK	2	1. Motivations. The crisis of classical physics and the rise of quantum mechanics. Mathematical formulation of quantum theory. Spectral problems in classical physics. 2. Elements of functional analysis. The discrete and essential spectra. Sobolev spaces. Quadratic forms. Schrödinger operators. 3. Stability of the essential spectrum. Weyl's theorem. Bound states. Variational and perturbation methods. 4. The role of the dimension of the Euclidean space. Criticality versus subcriticality. The Hardy inequality. Stability of matter. 5. Geometrical aspects. Glazman's classification of Euclidean domains and their basic spectral properties. 6. Vibrational systems. The symmetric rearrangement and the Faber-Krahn inequality for the principal frequency. 7. Quantum waveguides. Elements of differential geometry: curves, surfaces, manifolds. Effective dynamics. 8. Geometrically induced bound states and Hardy-type inequalities in tubes.
02GSKS	Groups of symmetry of quantum systems	ZK	2	The lecture - preferably for the students of Mathematical Physics - is aimed to introduce them to advanced topics connected with applications of group theory in quantum physics. Starting with the Wigner theorem on symmetry operations in quantum physics, the classification of projective representations of Lie groups as well as the superselection rules will be dealt with. The groups important in physics the Euclid, the Poincaré and the Galilei group will be treated by Mackeys method of induced representations.
02INB	Integrability and beyond	Z	2	Abstract: Hamiltonian systems and their integrals of motion. Hamilton-Jacobi equation and separation of variables. Classification of integrable systems with integrals polynomial in momenta. Superintegrability. Perturbative methods in the study of Hamiltonian systems.
02KCH	Quantum Chemistry	Z,ZK	3	Introduction to quantum chemistry. Students will acquire theoretical and practical skills to solve basic problems of theoretical quantum chemistry with focus on electronic structure.
02QIC	Quantum Information and Communication	Z,ZK	4	Quantum theory brought new ideas to the theory of information leading which ultimately lead to the theory of quantum information, computation and communication. The lecture introduces the basic concepts of quantum information e.g. quantum algorithms (Shors and Grovers), entanglement, quantum teleportation, quantum cryptography and quantum error correction. It also provides an introduction to modern parts of quantum information, e.g. measurement-based and adiabatic quantum computation and quantum walks.
02KO1	Quantum Optics 1	Z,ZK	4	Building upon classical optics, the course shows the construction of a semiclassical Quantum Optics theory of light and light-matter interaction. The aim of the lecture is to provide a robust theory allowing the qualitative and quantitative description of a broad range of quantum optical phenomena as well as some methods for practical computation.
02KO2	Quantum Optics 2	Z,ZK	4	This course completes Quantum Optics 1 by teaching the terminology and computational methods related to the reformulation of Quantum Optics in phase space. It also extends the application areas to continuum modes and dissipative processes. A concise survey of modern research topics in both theoretical and practical parts of Quantum Optics as well as its applications in further experimental research is also provided.
01KVGR1	Quantum Groups 1	Z	2	Quantum Algebra was originated in the 80s in the works of professor L. D. Faddeev and the Leningrad school on the inverse scattering method in order to solve integrable models. They have many applications in mathematics and mathematical physics such as the classification of nodes, in the theory of integrable systems and the string theory.
02KVK1	Quantum Circle 1	Z	2	Seminars of the Doppler Institute on topics of mathematical quantum physics for students and PhD. students.
02KVK2	Quantum Circle 2	Z	2	Seminars of the Doppler Institute on topics of mathematical quantum physics for students and PhD. students.
01MMNS	Mathematical Modelling of Non-linear Systems	ZK	3	The course consists of basic terms and results of the theory of finite- and infinitedimensional dynamical systems generated by evolutionary differential equations, and description of bifurcations and chaos. Second part is devoted to the explanation of basic results of the fractal geometry dealing with attractors of such dynamical systems.
02NGR	Numerical Relativity	ZK	2	The general theory of relativity is currently the most accurate theory of gravity. However, the great complexity of Einstein's equations means that we know only a very few analytically astrophysically relevant solutions. With the development of computers, however, the possibility to simulate spacetimes numerically has emerged, but this requires a significant reformulation of the standard theory. The main part of the course will therefore be devoted to formulating Einstein's equations in a form suitable for solving the initial problem. Specifics of general relativity then include coordinate freedom and the potential presence of physical singularities. In the course, we will also get to applications such as the localization of black holes and the extraction of gravitational waves.
02OKS	Open Quantum Systems	Z	2	Quantum description of composite subsystems and their subsystems, density operator. Pure and mixed states, entropy. Quantum correlations, entanglement, its basic properties and possible applications. Introduction to theory of generalized quantum measurement, positive operator-valued measure, physical realizations. Quantum operations, general description of state changes, superoperator theoretical framework, examples of quantum operations. Markovian quantum master equation, quantum dynamical semigroups. Basic models for description of decoherence and thermalization.
02PPKT	Advanced Topics of Quantum Theory	ZK	2	Linear operators in Hilbert spaces, the uncertainty relations, the canonical commutational relations, the Stone theorem, algebras of observables, the Schrödinger operators. There is an overlap with 01KF, contents is modified according to students´ requirements.
02QPRGA	Quantum Programming	Z	3	The goal of the course is to provide the basic skills for programming quantum computers, and to use these skills to develop an understanding of fundamental quantum communication protocols and quantum algorithms. The classes are combinations of lectures that introduce the essential concepts and tools, and interactive tutorials on how these concepts are implemented with Python programming language. Every week the students will be given Jupyter notebooks involving self-study materials and homework. The course is suitable for bachelor and masters students from all years and familiarity with quantum mechanics is not necessary. The classes are held entirely online to get the most out of the learning material and make it internationally accessible. The quantum SDK Qiskit will be used during the course. Use of own laptops with a quantum SDK installed before the course start is required.
02REL1	Relativistic Physics I	Z,ZK	6	Tensor analysis. Schwarzschild solution of Einstein equations. Black holes and gravitational collapse. Relativistic theory of stellar equilibria and evolution. Linearized theory and gravitational waves.

02REL2	Relativistic Physics 2	Z,ZK	6
Lagrangian formalism and conservation laws in general relativity. Initial value problem, 3+1 splitting and Gauss-Codazzi equations. Hamiltonian formalism in general relativity. Causal structure of spacetime. Geometry of timelike and null congruences.			
02RMMF	Solvable Models of Mathematical Physics	Z	2
Elementary methods for solving nonlinear differential equations occuring in mathematical physics are explained.			
02SKTPE1	Seminar on quantum field theory 1	Z	3
The lecture aims to introduce the students to advanced topics of quantum field theory. The focus is mainly on quantization with Feynmans functional integral.			
02SKTPE2	Seminar on quantum field theory 2	Z	3
The lecture aims to introduce the students to advanced topics of quantum field theory. The focus is mainly on quantization with Feynmans functional integral.			
01TG	Graph Theory	ZK	5
1. Basic notion of graph theory. 2. Edge and vertex connectivity (Menger Theorem). 3. Bipartite graphs. 4. Trees and forests. 5. Spanning trees (Matrix-Tree Theorem). 6. Euler tours and Hamilton cycles. 7. Maximal and perfect matching. 8. Edge coloring. 9. Flows in networks. 10. Vertex coloring. 11. Plannar graphs (Kuratowski theorem), vertex coloring of planar graphs. 12. Spectrum of the adjacency matrix. 13. Extremal graph theory.			
01NAH	Theory of Random Processes	ZK	3
The course is devoted in part to the basic notions of the general theory of random processes and partially to the theory of stationary processes and sequences both weakly and strongly stationary ones.			
02UST1	Introduction to Strings 1	Z	3
The goal of the lecture is to present the basics the (super)string theory			
02UST2	Introduction to Strings 2	Z	3
The goal of the lecture is to develop the basics the (super)string Theory explained in UST1			
01VAM	Variational Methods	ZK	3
The course is devoted to the methods of classical variational calculus - functional extrema by Euler equations, second functional derivative, convexity or monotonicity. Further, it contains investigation of quadratic functional, generalized solution, Sobolev spaces and variational problem for elliptic PDE's.			

List of courses of this pass:

Code	Name of the course	Completion	Credits
01ASY	Asymptotical Methods	Z,ZK	3
Examples. Addition parts of mathematical analysis (generalized Lebesgue integral, parametric integrals.) Asymptotic relations a expansions - properties; algebraical and analytical operations. Applied asymptotics of sequences and sums; integrals of Laplace and Fourier type.			
01FAN3	Functional Analysis 3	Z,ZK	5
Advanced parts of functional analysis needed for theory of representations of Lie groups and quantum theory. Compact operators, their ideals, unbounded selfadjoint operators, theory of selfadjoint extension of symmetric operators, Stones theorem, quadratic forms and Bochner integral. The basics of Banach algebras and C*-algebras.			
01KVGR1	Quantum Groups 1	Z	2
Quantum Algebra was originated in the 80s in the works of professor L. D. Faddeev and the Leningrad school on the inverse scattering method in order to solve integrable models. They have many applications in mathematics and mathematical physics such as the classification of nodes, in the theory of integrable systems and the string theory.			
01MMNS	Mathematical Modelling of Non-linear Systems	ZK	3
The course consists of basic terms and results of the theory of finite- and infinitedimensional dynamical systems generated by evolutionary differential equations, and description of bifurcations and chaos. Second part is devoted to the explanation of basic results of the fractal geometry dealing with attractors of such dynamical systems.			
01NAH	Theory of Random Processes	ZK	3
The course is devoted in part to the basic notions of the general theory of random processes and partially to the theory of stationary processes and sequences both weakly and strongly stationary ones.			
01SPEC	Geometrical Aspects of Spectral Theory	ZK	2
1. Motivations. The crisis of classical physics and the rise of quantum mechanics. Mathematical formulation of quantum theory. Spectral problems in classical physics. 2. Elements of functional analysis. The discrete and essential spectra. Sobolev spaces. Quadratic forms. Schrödinger operators. 3. Stability of the essential spectrum. Weyl's theorem. Bound states. Variational and perturbation methods. 4. The role of the dimension of the Euclidean space. Criticality versus subcriticality. The Hardy inequality. Stability of matter. 5. Geometrical aspects. Glazman's classification of Euclidean domains and their basic spectral properties. 6. Vibrational systems. The symmetric rearrangement and the Faber-Krahn inequality for the principal frequency. 7. Quantum waveguides. Elements of differential geometry: curves, surfaces, manifolds. Effective dynamics. 8. Geometrically induced bound states and Hardy-type inequalities in tubes.			
01TG	Graph Theory	ZK	5
1. Basic notion of graph theory. 2. Edge and vertex connectivity (Menger Theorem). 3. Bipartite graphs. 4. Trees and forests. 5. Spanning trees (Matrix-Tree Theorem). 6. Euler tours and Hamilton cycles. 7. Maximal and perfect matching. 8. Edge coloring. 9. Flows in networks. 10. Vertex coloring. 11. Plannar graphs (Kuratowski theorem), vertex coloring of planar graphs. 12. Spectrum of the adjacency matrix. 13. Extremal graph theory.			
01VAM	Variational Methods	ZK	3
The course is devoted to the methods of classical variational calculus - functional extrema by Euler equations, second functional derivative, convexity or monotonicity. Further, it contains investigation of quadratic functional, generalized solution, Sobolev spaces and variational problem for elliptic PDE's.			
02ALT	Algebraic Topology	Z,ZK	4
A study of modern mathematical and theoretical physics requires one to acquire an ever increasing knowledge of mathematical apparautus. The main goal of this course is to acquaint students with basic methods used in algebraic topology, namely elements of category theory, homototopies, homological algebra and cohomology. An important objective is to enhance the mathematical language by concepts appearing universally across disciplines like differential geometry and abstract algebra. During excercise sessions, students will try practical calculations of introduced mathematical structures.			
02COX	Coxeter Groups	Z	2
The course is an introduction to the theory of Coxeter groups and their invariant theory. The case of the finite Coxeter groups - the reflection groups and their properties are studied. The notions of the Weyl chamber and length are defined. General theory of the Coxeter groups, the corresponding bilinear forms and the theory of their classification represent abstract generalization of the reflection groups. The study of affine Weyl groups and related objects forms basic example of infinite Coxeter groups. As an introduction to the invariant theory the MacDonald identity and the Weyl identity are presented.			

02DPMF1	Master Thesis 1	Z	10
The diploma project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02DPMF2	Master Thesis 2	Z	20
The diploma project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02DSMF	Diploma Seminar	Z	1
In the first part of the seminar, students familiarize themselves with the general principles of publishing and presenting scientific work and the formal requirements for diploma projects at the faculty. The second part is designed as a practical training for the defence of the diploma project. The students give oral presentations of the current state of the research results achieved during the work on their projects. Each presentation is followed by a discussion on scientific matters as well as on the possibilities of improving the students performance.			
02FG	Physics of graphene described by Dirac equation	Z	2
General description of crystal. Tight-binding model of graphene and its approximation in terms of Dirac equation.Transport of Dirac fermions in graphene in presence of external fields and related phenomena. Bilayer graphene, its description and properties in the external magnetic field. Carbon nanotubes, their classification. Basic description of graphene nanoribbons,boundary conditions and energy. Dirac fermions in curved space, fullerenes. Other Dirac materials.			
02GMF2	Geometric Methods in Physics 2	Z,ZK	5
A theory of gauge fields forms the foundation of contemporary particle physics, namely of the Standard Model. The main goal of this course to to acquaint students with the mathematical apparatus required for its geometric description. We will focus on theory of principal fiber bundles and the interpretation of gauge fields as connection forms on principal fiber bundles. All theoretical concepts are demonstrated on particular examples, e.g. frame bundle, Hopf fibration and Yang-Mills field.			
02GR	Groups and Representations	Z,ZK	3
The aim of the lectures is to acquaint students with the basic concepts of discrete group theory and their representations. The student will be thoroughly acquainted with the methods of classification of finite groups, decomposition of groups into direct and semidirect products, and with the properties of reducible and irreducible representations.			
02GSKS	Groups of symmetry of quantum systems	ZK	2
The lecture - preferably for the students of Mathematical Physics - is aimed to introduce them to advanced topics connected with applications of group theory in quantum physics. Starting with the Wigner theorem on symmetry operations in quantum physics, the classification of projective representations of Lie groups as well as the superselection rules will be dealt with. The groups important in physics the Euclid, the Poincaré and the Galilei group will be treated by Mackeys method of induced representations.			
02INB	Integrability and beyond	Z	2
Abstract: Hamiltonian systems and their integrals of motion. Hamilton-Jacobi equation and separation of variables. Classification of integrable systems with integrals polynomial in momenta. Superintegrability. Perturbative methods in the study of Hamiltonian systems.			
02KCH	Quantum Chemistry	Z,ZK	3
Introduction to quantum chemistry. Students will acquire theoretical and practical skills to solve basic problems of theoretical quantum chemistry with focus on electronic structure.			
02KFA	Quantum Physics	Z,ZK	6
The goal of the lecture is formulating and developing quantum theory as a physically motivated, but mathematically rigorous theory built upon the analysis of bounded and unbounded linear operators on separable Hilbert spaces. Previous knowledge of quantum mechanics is an advantage but not a predisposition for the course. The pivot point is the establishing of the main postulates of the theory and deriving their consequences for model systems, as well as a detailed study of the most commonly used observables in quantum mechanics. The lecture focuses on the exactness and proofs of the statements. Some common mistakes resulting from breaking the assumptions of these are also discussed.			
02KO1	Quantum Optics 1	Z,ZK	4
Building upon classical optics, the course shows the construction of a semiclassical Quantum Optics theory of light and light-matter interaction. The aim of the lecture is to provide a robust theory allowing the qualitative and quantitative description of a broad range of quantum optical phenomena as well as some methods for practical computation.			
02KO2	Quantum Optics 2	Z,ZK	4
This course completes Quantum Optics 1 by teaching the terminology and computational methods related to the reformulation of Quantum Optics in phase space. It also extends the application areas to continuum modes and dissipative processes. A concise survey of modern research topics in both theoretical and practical parts of Quantum Optics as well as its applications in further experimental research is also provided.			
02KTPA1	Quantum Field Theory 1	Z,ZK	8
The lecture aims to introduce the students to both fundamental and applied parts of quantum field theory. The focus is in particular on equations of relativistic quantum mechanics, canonical quantization of scalar and bispinor field, perturbation theory (Feynmans rules) and basics of renormalization. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity.			
02KTPA2	Quantum Field Theory 2	Z,ZK	8
The lecture aims at introducing the students to the Feynmans functional integral and its applications. The focus is on broadening the knowledge of modern parts of relativistic and non-relativistic quantum field theory and statistical physics. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity.			
02KVK1	Quantum Circle 1	Z	2
Seminars of the Doppler Institute on topics of mathematical quantum physics for students and PhD. students.			
02KVK2	Quantum Circle 2	Z	2
Seminars of the Doppler Institute on topics of mathematical quantum physics for students and PhD. students.			
02LAG	Lie Algebras and Lie Groups	Z,ZK	7
The aim of the lectures is get students familiar with the basic concepts of the theory of Lie groups and Lie algebras, and their finite-dimensional representations. The students will also learn Cartan's classification of simple complex Lie algebras, which is the fundamental result in this field of mathematics, including its derivation. Emphasis is put on detailed investigation of explicit examples of the introduced mathematical structures and their applications.			
02NGR	Numerical Relativity	ZK	2
The general theory of relativity is currently the most accurate theory of gravity. However, the great complexity of Einstein's equations means that we know only a very few analytically astrophysically relevant solutions. With the development of computers, however, the possibility to simulate spacetimes numerically has emerged, but this requires a significant reformulation of the standard theory. The main part of the course will therefore be devoted to formulating Einstein's equations in a form suitable for solving the initial problem. Specifics of general relativity then include coordinate freedom and the potential presence of physical singularities. In the course, we will also get to applications such as the localization of black holes and the extraction of gravitational waves.			
02OKS	Open Quantum Systems	Z	2
Quantum description of composite subsystems and their subsystems, density operator. Pure and mixed states, entropy. Quantum correlations, entanglement, its basic properties and possible applications. Introduction to theory of generalized quantum measurement, positive operator-valued measure, physical realizations. Quantum operations, general description of state changes, superoperator theoretical framework, examples of quantum operations. Markovian quantum master equation, quantum dynamical semigroups. Basic models for description of decoherence and thermalization.			

02PPKT	Advanced Topics of Quantum Theory	ZK	2
Linear operators in Hilbert spaces, the uncertainty relations, the canonical commutational relations, the Stone theorem, algebras of observables, the Schrödinger operators. There is an overlap with 01KF, contents is modified according to students´ requirements.			
02QIC	Quantum Information and Communication	Z,ZK	4
Quantum theory brought new ideas to the theory of information leading which ultimately lead to the theory of quantum information, computation and communication. The lecture introduces the basic concepts of quantum information e.g. quantum algorithms (Shors and Grovers), entanglement, quantum teleportation, quantum cryptography and quantum error correction. It also provides an introduction to modern parts of quantum information, e.g. measurement-based and adiabatic quantum computation and quantum walks.			
02QPRGA	Quantum Programming	Z	3
The goal of the course is to provide the basic skills for programming quantum computers, and to use these skills to develop an understanding of fundamental quantum communication protocols and quantum algorithms. The classes are combinations of lectures that introduce the essential concepts and tools, and interactive tutorials on how these concepts are implemented with Python programming language. Every week the students will be given Jupyter notebooks involving self-study materials and homework. The course is suitable for bachelor and masters students from all years and familiarity with quantum mechanics is not necessary. The classes are held entirely online to get the most out of the learning material and make it internationally accessible. The quantum SDK Qiskit will be used during the course. Use of own laptops with a quantum SDK installed before the course start is required.			
02REL1	Relativistic Physics I	Z,ZK	6
Tensor analysis. Schwarzschild solution of Einstein equations. Black holes and gravitational collapse. Relativistic theory of stellar equilibria and evolution. Linearized theory and gravitational waves.			
02REL2	Relativistic Physics 2	Z,ZK	6
Lagrangian formalism and conservation laws in general relativity. Initial value problem, 3+1 splitting and Gauss-Codazzi equations. Hamiltonian formalism in general relativity. Causal structure of spacetime. Geometry of timelike and null congruences.			
02RMMF	Solvable Models of Mathematical Physics	Z	2
Elementary methods for solving nonlinear differential equations occuring in mathematical physics are explained.			
02SKTPE1	Seminar on quantum field theory 1	Z	3
The lecture aims to introduce the students to advanced topics of quantum field theory. The focus is mainly on quantization with Feynmans functional integral.			
02SKTPE2	Seminar on quantum field theory 2	Z	3
The lecture aims to introduce the students to advanced topics of quantum field theory. The focus is mainly on quantization with Feynmans functional integral.			
02UST1	Introduction to Strings 1	Z	3
The goal of the lecture is to present the basics the (super)string theory			
02UST2	Introduction to Strings 2	Z	3
The goal of the lecture is to develop the basics the (super)string Theory explained in UST1			
02VPSFA	Selected Topics in Statistical Physics and Thermodynamics	Z,ZK	7
The course concentrates on some advanced topics of statistical mechanics not discussed in the basic course on thermodynamics and statistical physics. Question concerning density matrices, the behaviours of nonideal gases and its macroscopic description, microscopic description of phase transitions, the role of fluctuations are addressed in detail.			
02VUMF1	Research Project 1	Z	6
The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02VUMF2	Research Project 2	KZ	8
The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions.			
02ZS	Winter School of Mathematical Physics	Z	1
The aim of the winter school of mathematical physics is to significantly improve presentation skills of the students and their ability to follow specialized conference presentations in English. Each student presents a specialized talk in English on the topic of his/her own research. The goal is to create such suitable conditions that motivate students towards a rigorous formulation of their own research together with high quality specialized presentation and abstract. The scientific level of the student presentations is guaranteed by audience comprising experts from CTU and other universities.			

For updated information see http://bilakniha.cvut.cz/en/FF.html
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