Study plan

Name of study plan: Matematické inženýrství

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department: Welcome page
Garantor of the study branch:
Program of study: Mathematical Engineering
Type of study: Follow-up master full-time
Required credits: 8
Elective courses credits: 112
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: NMSPMI1
Name of the group: MDP P_MIN 1st year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 11 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
01FAN3	**Functional Analysis 3** *Pavel Šťovíček* ***Pavel Šťovíček*** *Pavel Šťovíček (Gar.)*	Z,ZK	5	2P+2C	Z	P
01MMDY	**Mathematical Methods in Fluid Dynamics 1** *Pavel Strachota* ***Pavel Strachota*** *Pavel Strachota (Gar.)*	ZK	2	2P+0C	Z	P
01MKP	**Finite Element Method** *Michal Beneš* ***Michal Beneš*** *Michal Beneš (Gar.)*	ZK	3	1P+1C	L	P
01NELO	**Nonlinear Optimization** *Radek Fučík* ***Radek Fučík*** *Radek Fučík (Gar.)*	ZK	4	3P+0C		P
01PNL	**Advanced Methods of Numerical Linear Algebra** *Jiří Mikyška* ***Jiří Mikyška*** *Jiří Mikyška (Gar.)*	ZK	2	2P+0C		P
01TG	**Graph Theory** *Jan Volec, Petr Ambrož* ***Petr Ambrož*** *Petr Ambrož (Gar.)*	ZK	5	4P+0C		P
01TIN	**Information Theory** *Tomáš Hobza* ***Tomáš Hobza*** *Tomáš Hobza (Gar.)*	ZK	2	2+0	Z	P
01NAH	**Theory of Random Processes** *Jan Vybíral* ***Jan Vybíral*** *Jan Vybíral (Gar.)*	ZK	3	3+0	Z	P
01VAM	**Variational Methods** *Michal Beneš* ***Michal Beneš*** *Michal Beneš (Gar.)*	ZK	3	1P+1C	Z	P
01VUMM1	**Research Project 1** *Čestmír Burdík* ***Čestmír Burdík*** *Čestmír Burdík (Gar.)*	Z	6	0+6	Z	P
01VUMM2	**Research Project 2** *Čestmír Burdík* ***Čestmír Burdík*** *Čestmír Burdík (Gar.)*	KZ	8	0+8	L	P

Characteristics of the courses of this group of Study Plan: Code=NMSPMI1 Name=MDP P_MIN 1st year

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.

01MMDY	Mathematical Methods in Fluid Dynamics 1	ZK	2

First, the differential equations representing the conservation laws of fluid flow are briefly derived and reviewed. Next, the problems for the resulting equations are formulated, focusing on boundary conditions specification. The reference problem undergoes numerical analysis with emphasis on explaining the weak solution and its role in describing real phenomena. In the second part, important problems are introduced, involving fluid flow and other effects (heat transfer, chemical reactions, multiphase nature) and an adequate mathematical description is chosen.

01MKP	Finite Element Method	ZK	3

The course is devoted to the mathematical theory of the finite element method numerically solving boundary-value and initial-boundary-value problems for partial differential equations. Mathematical properties of the method are explained. The approximation error estimates are derived.

01NELO	Nonlinear Optimization	ZK	4

Nonlinear optimization problems find their application in may areas of applied mathematics. The lecture covers the basics of mathematical programming theory with emphasis on convex optimization and basic methods for unconstrained and constrained optimization. The lecture is supplemented by illustrative examples.

01PNL	Advanced Methods of Numerical Linear Algebra	ZK	2

Representation of real numbers in computers, behaviour of rounding errors during numerical computations, sensitivity of a problem, numerical stability of an algorithm. We will analyse sensitivity of the eigenvalues of a given matrix and sensitivity of roots of systems of linear algebraic equations. Then, the backward analysis of these problems will be performed. The second part of the course is devoted to the methods of QR-decomposition, least squares problem, and to several modern Krylov subspace methods for the solution of systems of linear algebraic equations and the Lanczos method for approximation of the eigenvalues of a symmetric square matrix.

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.

01TIN	Information Theory	ZK	2

Information theory explores the fundamental limits of the representation and transmission of information. We will focus on the definition and implications of (information) entropy, the source coding theorem, and the channel coding theorem. These concepts provide a vital background for researchers in the areas of data compression, signal processing, controls, and pattern recognition.

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.

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.

01VUMM1	Research Project 1	Z	6

Research project on the selected topic under the supervision. Supervision and regular checking of the research project under preparation.

01VUMM2	Research Project 2	KZ	8

Research project on the selected topic under the supervision. Supervision and regular checking of the research project under preparation.

Code of the group: NMSPMI2
Name of the group: NMS P_MIN 2nd year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 7 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
01AOM	**Applications of Optimization Methods** *Tomáš Oberhuber* ***Tomáš Oberhuber*** *Tomáš Oberhuber (Gar.)*	ZK	2	1P+1C		P
01ASY	**Asymptotical Methods** *Jiří Mikyška* ***Jiří Mikyška*** *Jiří Mikyška (Gar.)*	Z,ZK	3	2+1	Z	P
01DPMM1	**Master Thesis 1** *Čestmír Burdík* ***Čestmír Burdík*** *Čestmír Burdík (Gar.)*	Z	10	0+10	Z	P
01DPMM2	**Master Thesis 2** *Čestmír Burdík* ***Čestmír Burdík*** *Čestmír Burdík (Gar.)*	Z	20	0+20	L	P
01MMNS	**Mathematical Modelling of Non-linear Systems** *Michal Beneš* ***Michal Beneš*** *Michal Beneš (Gar.)*	ZK	3	1P+1C	Z	P
01MRMMI	**Methods for Sparse Matrices** *Jiří Mikyška* ***Jiří Mikyška*** *Jiří Mikyška (Gar.)*	KZ	2	2P+0C		P
01DISE	**Diploma Seminar** *Čestmír Burdík* ***Čestmír Burdík*** *Čestmír Burdík (Gar.)*	Z	1	0P+2S		P

Characteristics of the courses of this group of Study Plan: Code=NMSPMI2 Name=NMS P_MIN 2nd year

01AOM	Applications of Optimization Methods	ZK	2

Aim of this course is to enhance the knowledge of the optimization methods and show their practical applications. Number of methods are applied on the support-vector machines and subsequently, methods for large problems and training of deep artificial neural networks are explained. Finaly, advanced methods for regret minimization or sparsity inducing methods are explained. All methods are demonstrated on real problems.

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.

01DPMM1	Master Thesis 1	Z	10

Master's thesis preparation.

01DPMM2	Master Thesis 2	Z	20

Master's thesis preparation.

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.

01MRMMI	Methods for Sparse Matrices	KZ	2

The course is aimed at utilization of sparse matrices in direct methods for solution of large systems of linear algebraic equations. The course will cover the decomposition theory for symmetric and positive definite matrices. Theoretic results will be further applied for solution of more general systems. Main features of the methods and common implementation issues will be covered.

01DISE	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.

Name of the block: Compulsory elective courses
Minimal number of credits of the block: 8
The role of the block: PV

Code of the group: NMSPMIPV1
Name of the group: NMS P_MIN Required optional courses 1st year
Requirement credits in the group: In this group you have to gain at least 8 credits
Requirement courses in the group:
Credits in the group: 8
Note on the group: Studenti si povinně zapisují předměty alespoň za 8 kreditů.

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**
01PDE	**Modern theory of partial differential equations** *Matěj Tušek* ***Matěj Tušek*** *Matěj Tušek (Gar.)*	Z,ZK	4	2P+1C		PV
01LBM	**Lattice Boltzmann Method** *Radek Fučík* ***Radek Fučík*** *Radek Fučík (Gar.)*	KZ	2	1P+1C		PV
01NMDT	**Numerical Methods in Fluid Dynamics** *Pavel Strachota* ***Pavel Strachota*** *Pavel Strachota (Gar.)*	ZK	2	2P+0C		PV
01PAA	**Parallel Algorithms and Architectures** *Tomáš Oberhuber* ***Tomáš Oberhuber*** *Tomáš Oberhuber (Gar.)*	KZ	4	2P+1C	L	PV
01PALG	**Advanced Algorithmization** *Tomáš Oberhuber* ***Tomáš Oberhuber*** *Tomáš Oberhuber (Gar.)*	KZ	2	1P+1C		PV
01SKE	**System Reliability and Clinical Experiments** *Václav Kůs* ***Václav Kůs*** *Václav Kůs (Gar.)*	KZ	3	2+0	L	PV
01SDR	**Stochastic Differential Equations** *Michal Beneš* ***Michal Beneš*** *Michal Beneš (Gar.)*	ZK	2	2P+0C		PV
01TEMA	**Matrix Theory** *Edita Pelantová* ***Edita Pelantová*** *Edita Pelantová (Gar.)*	Z	3	2+0	L	PV

Characteristics of the courses of this group of Study Plan: Code=NMSPMIPV1 Name=NMS P_MIN Required optional courses 1st year

01PDE	Modern theory of partial differential equations	Z,ZK	4

1. Sobolev spaces. 2. Definition, completeness, examples. 3. Continuous and compact embedding theorems. 4. Trace theorem. 5. Weak solution (importance, derivation of the weak formulation). 6. Elliptic PDE of Second Order. 7. Existence and uniqueness of weak solutions (Lax-Milgram theorem). 8. Regularity of weak solutions. 9. Relation to the calculus of variations, Poincaré inequality. 10. Maximum principle for classical and weak solutions.

01LBM	Lattice Boltzmann Method	KZ	2

The lattice Boltzmann method (LBM) is a modern numerical method allowing the solution of non-stationary partial differential equations by solving the Boltzmann transport equation for unknown densities of the particle probability distribution function. The course introduces the basics of the LBM theory, derived equivalent partial differential equations for an advection-diffusion problem and for the incompressible Newtonian flluid flow, and the basic properties of the numerical scheme are derived. The exercises are then devoted to the practical implementation and computations of LBM using the computational infrastructure at FNSPE CTU in Prague, especially with the focus on GPU computing.

01NMDT	Numerical Methods in Fluid Dynamics	ZK	2

The course is focused on the design and properties of numerical methods for solving fluid flow equations. Focus is put mainly on the finite volume method whose classical and advanced schemes are derived. Selected schemes are analyzed in terms of stability. The second part is devoted to advanced numerical schemes used in practice. The matter is concluded by a brief summary of alternative numerical approaches for fluid flow simulation and by a demonstration of visualization techniques for simulation results.

01PAA	Parallel Algorithms and Architectures	KZ	4

This course deals with the parallel data processing. It is important in situations when one processing unit (CPU) is not powerful enough to finish given task in reasonable time. When designing parallel algorithms, good knowledge of the parallel architectures is important. Therefore these architectures are studied as a part of this course too.

01PALG	Advanced Algorithmization	KZ	2

Keywords: String algorithms, graph algorithms, dynamic programming, suffix tress, graph cuts, numerical methods for solution of partial differential equations.

01SKE	System Reliability and Clinical Experiments	KZ	3

The main goal of the subject is to provide the mathematical principles of reliability theory and techniques of survival data analysis, reliability of component systems, asymptotic methods for reliability, concept of experiments under censoring and their processing in clinical trials (life-time models). The techniques are illustrated and tested within practical examples originating from lifetime material experiments and clinical trials.

01SDR	Stochastic Differential Equations	ZK	2

The class is devoted to an introduction to stochastic differential equations and their applications. The content includes stochastic processes, Itô integral and solution of stochastic differential equations. The applications in filtering, diffusion and optimal control are mentioned as well.

01TEMA	Matrix Theory	Z	3

The subject deals mainly with: 1) similarity of matrices and canonical forms of matrices 2) Perron-Frobenius theory and its applications 3) tensor product 4) Hermitian and positive semidefinite matrices

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

Code of the group: NMSPMIV
Name of the group: MDP P_MIN 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
12DRP	**Differential Equations on Computer** *Richard Liska **Richard Liska** Richard Liska (Gar.)*	Z,ZK	5	2+2	Z	V
01DIZO	**Digital Image Processing** *Barbara Zitová **Barbara Zitová** Barbara Zitová (Gar.)*	ZK	4	2P+2C		V
01FIMA	**Financial and Insurance Mathematics** *Joel Horowitz **Joel Horowitz** Joel Horowitz (Gar.)*	ZK	2	2P+0C	Z	V
01SPEC	**Geometrical Aspects of Spectral Theory** *David Krejčiřík **David Krejčiřík** David Krejčiřík (Gar.)*	ZK	2	2+0	L	V
18HA	**Heuristic Algorithms** *Jaromír Kukal **Jaromír Kukal** Jaromír Kukal (Gar.)*	ZK	4	2P+2C	L	V
01KOS	**Compressed Sensing** *Jan Vybíral **Jan Vybíral** Jan Vybíral (Gar.)*	ZK	2	2+0	Z	V
02QIC	**Quantum Information and Communication** *Aurél Gábor Gábris **Aurél Gábor Gábris** Martin Štefaňák (Gar.)*	Z,ZK	4	3P+1C	Z	V
01MAL	**Mathematical Logic** *Petr Cintula **Petr Cintula** Petr Cintula (Gar.)*	Z,ZK	4	2+1		V
01MBM	**Mathematical techniques in biology and medicine** *Václav Klika **Václav Klika** Václav Klika (Gar.)*	Z,ZK	3	2+1	L	V
18MEMC	**Monte Carlo Method** *Jaromír Kukal, Miroslav Virius **Miroslav Virius** Miroslav Virius (Gar.)*	Z,ZK	4	2P+2C	Z	V
01SMF	**Modern Trends in Corporate Information Technologies** *Tomáš Oberhuber **Tomáš Oberhuber** Tomáš Oberhuber (Gar.)*	Z	2	2	L	V
18OOP	**Object Oriented Programming** *Miroslav Virius **Miroslav Virius** Miroslav Virius (Gar.)*	Z	2	2C	Z	V
18PCP	**Advanced C++** *Miroslav Virius **Miroslav Virius** Miroslav Virius (Gar.)*	Z,ZK	4	2P+2C	L	V
01PAMF	**Mainframe Programming in Assembler** ***Tomáš Oberhuber** Tomáš Oberhuber (Gar.)*	Z	2	2	L	V
01DPR	**Pre-diploma Practice** *Michal Beneš **Michal Beneš** Michal Beneš (Gar.)*	Z	4	2XT		V
01SUP	**Start-up Project** *Přemysl Rubeš **Přemysl Rubeš** Přemysl Rubeš (Gar.)*	KZ	2	2P+0C		V
01SVK	**Student's Scientific Conference** ***Jiří Mikyška** Jiří Mikyška (Gar.)*	Z	1	5 dní		V
01TEC	**Number Theory** *Edita Pelantová, Zuzana Masáková **Zuzana Masáková** Zuzana Masáková (Gar.)*	ZK	5	4P+0C		V
01UMF	**Introduction to Mainframe** *Tomáš Oberhuber **Tomáš Oberhuber** Tomáš Oberhuber (Gar.)*	Z	2	1P+1C	Z	V
01URG	**Introduction to Riemannian geometry** *David Krejčiřík **David Krejčiřík** David Krejčiřík (Gar.)*	ZK	2	2+0	Z	V
01UTS	**Introduction to the Theory of Semigroups** *Václav Klika **Václav Klika** Václav Klika (Gar.)*	ZK	3	2P+0C		V
02VPSFA	**Selected Topics in Statistical Physics and Thermodynamics** *Igor Jex **Martin Štefaňák** Igor Jex (Gar.)*	Z,ZK	7	4P+2C	Z	V

Characteristics of the courses of this group of Study Plan: Code=NMSPMIV Name=MDP P_MIN Optional courses

12DRP	Differential Equations on Computer	Z,ZK	5

Ordinary differential equations, analytical methods; Ordinary differential equations, numerical methods, Runge-Kutta methods, stability; Partial differential equations, analysis, hyperbolik, parabolic and elliptic equations, posedness of differential equaitons; Partial differential equations, numerical solution, finite difference methods, difference schemes, order of approximation, stability, convergence, modified equation, diffusion, dispersion; Conservation laws and their numerical solution, shallow water equations, Euler equations, Lagrangian methods, ALE methods; Practical computation in Matlab system for numerics and Maple for analysis of schemes.

01DIZO	Digital Image Processing	ZK	4

image sampling and quantization, Shannon theorem, aliasing basic image operations, histogram, contrast stretching, noise removal, image sharpening linear filtering in the spatial and frequency domains, convolution, Fourier transform edge detection, corner detection feature detection image degradations and their modelling, inverse and Wiener filtering, restoration of motion-blurred and out-of-focus blurred images image segmentation mathematical morphology image registration and matching

01FIMA	Financial and Insurance Mathematics	ZK	2

This course is an introduction to the problems of life and non-life insurance and financial mathematics.

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.			
18HA	Heuristic Algorithms	ZK	4
Heuristic algorithms of optimization operates on discrete or continuous domains. Brutal force, stochastic, greedy, physically, biologically and sociologically motivated heuristic are included, used for optimum finding and compared.			
01KOS	Compressed Sensing	ZK	2
The lecture will introduce basic concepts of the theory of compressed sensing an area founded in 2006 in the works of D. Donoho, E. Candes, and T. Tao. This theory studies the search for sparse solutions of underdetermined systems of linear equations. Due to the applications of sparse representations in electric engeneering and signal processing, this theory was quickly used in many different fields. After the first survey lecture, we will study the mathematical foundations of the theory. We prove general NP-completeness of the search for sparse solutions of systems of linear equations. We introduce conditions which ensure also existence of more effective solvers and show, that these are satisfied for example for Gaussian random matrices. As an effective solution method, we will analyze l1-minimization and Orthogonal Matching Pursuit. We will also study stability and robustness of the obtained results with respect to the corruption of measurements and the optimality of the results.			
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.			
01MAL	Mathematical Logic	Z,ZK	4
Logic is in the same time an object studied by mathematics and the language used to formalize and study mathematics. The goal of the course is to introduce basic notion of results of classical mathematical logic. 1.Propositions, evaluation, tautologies, axioms, theorems, soundness, completeness, and decidability of Hilbert and Gentzen style propositional calculi. 2.Language of predicate calculus, terms, formulas, relational structures, satisfiability, truth, tautologies, axioms, theorems, soundness, model constructions. 3.Gödel completeness theorem, Skolem and Herbrand theorems. 4.The first and the second Gödel theorems on incompleteness of Peano arithmetics and undecidability of predicate calculus.			
01MBM	Mathematical techniques in biology and medicine	Z,ZK	3
Spatially independent models; enzyme kinetics; excitable system; reaction-diffusion equations; travelling waves; pattern formation; conditions for Turing instability, the effect of domain size; the concept of stability in PDEs, spectrum of a linear operator, semigroups.			
18MEMC	Monte Carlo Method	Z,ZK	4
This courseis devoted to the numerical method Monte Carlo and to its selected applications.			
01SMF	Modern Trends in Corporate Information Technologies	Z	2
The course is devoted to mainframe administration basics. After introduction to mainframe hardware the following lectures covers security, transaction systems, virtualization and non-relational databases in the mainframe environment.			
18OOP	Object Oriented Programming	Z	2
This course consists of the contributions of students concerning given topics concerned on technologies uded in program development.			
18PCP	Advanced C++	Z,ZK	4
This lecture covers the virtual inheritance,variadic templetes, template metaprogramming, template libraries design and implementation, tools for data type processing in compile time and for the advanced diagnostic of the templates, concepts, coroutines, modules, ranges, views and other tools introduced in C++ 20, application of the multithreading (execution parallelization).			
01PAMF	Mainframe Programming in Assembler	Z	2
In this course the basics of programming in z/OS are explained namely the programming in assembler. Basic instructions, macros, I/O operations, DLL library loading and some other topics are discussed.			
01DPR	Pre-diploma Practice	Z	4
The practice serves for broadening knowledge related to the contents of the Masters Thesis, for close interaction with the supervisor and focused two-week activity related to the project. The course should support the emergence of results that will become part of the masters degree project. The practice is usually carried out at the supervisor's workplace.			
01SUP	Start-up Project	KZ	2
01SVK	Student's Scientific Conference	Z	1
This is the active participation of the student in one of the approved student conferences. The list of such conferences is defined by the course guarantor.			
01TEC	Number Theory	ZK	5
1. Algebraic and transcendental numbers 2. Algebraic number fields, field isomorphisms 3. Rational approximations, continued fractions 4. Diophantic equations, Pell's equation 5. Rings of integers in algebraic number fields and divisibility 6. Number representation in non-integer bases, finite and periodic expansions			
01UMF	Introduction to Mainframe	Z	2
In this course we teach the mainframe architecture. We explain how to operate the system z/OS, how to start a job using the JCL and we explain some differences when programming in C/C++ for z/OS:			
01URG	Introduction to Riemannian geometry	ZK	2
This lecture is intended for an advanced undergraduate having possibly (but not necessarily) already taken a basic course on topological and differential manifolds. In addition to understanding the geometric meaning of curvature and its intimate relationship to topology, the student will learn the basic apparatus of Riemannian geometry suitable for further study of modern parts of mathematics and mathematical physics. Possible extension of this lecture is the geometric analysis of partial differential equations on Riemannian manifolds.			
01UTS	Introduction to the Theory of Semigroups	ZK	3
It is known that a system of linear ordinary differential equations can be solved by virtue of the matrix exponential. However, the extension to partial differential equations is not straightforward. For example in the case of heat equation the matrix is replaced by Laplace operator which is not bounded and the series for the exponential will not converge. Moreover, solutions of the heat equation exist in general only for positive times and hence the solution operator can be at best a semigroup. The aim of the course is to provide a mathematical foundation for these types of problems and extend the concept of stability from ordinary differential equations, which is again in relation to spectrum of a linear operator.			
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.			

List of courses of this pass:

<table>
<tr><th>Code</th><th>Name of the course</th><th>Completion</th><th>Credits</th></tr>
<tr><td>01AOM</td><td>Applications of Optimization Methods</td><td>ZK</td><td>2</td></tr>
<tr><td colspan="4">Aim of this course is to enhance the knowledge of the optimization methods and show their practical applications. Number of methods are applied on the support-vector machines and subsequently, methods for large problems and training of deep artificial neural networks are explained. Finaly, advanced methods for regret minimization or sparsity inducing methods are explained. All methods are demonstrated on real problems.</td></tr>
<tr><td>01ASY</td><td>Asymptotical Methods</td><td>Z,ZK</td><td>3</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>01DISE</td><td>Diploma Seminar</td><td>Z</td><td>1</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>01DIZO</td><td>Digital Image Processing</td><td>ZK</td><td>4</td></tr>
<tr><td colspan="4">image sampling and quantization, Shannon theorem, aliasing basic image operations, histogram, contrast stretching, noise removal, image sharpening linear filtering in the spatial and frequency domains, convolution, Fourier transform edge detection, corner detection feature detection image degradations and their modelling, inverse and Wiener filtering, restoration of motion-blurred and out-of-focus blurred images image segmentation mathematical morphology image registration and matching</td></tr>
<tr><td>01DPMM1</td><td>Master Thesis 1</td><td>Z</td><td>10</td></tr>
<tr><td colspan="4">Master's thesis preparation.</td></tr>
<tr><td>01DPMM2</td><td>Master Thesis 2</td><td>Z</td><td>20</td></tr>
<tr><td colspan="4">Master's thesis preparation.</td></tr>
<tr><td>01DPR</td><td>Pre-diploma Practice</td><td>Z</td><td>4</td></tr>
<tr><td colspan="4">The practice serves for broadening knowledge related to the contents of the Masters Thesis, for close interaction with the supervisor and focused two-week activity related to the project. The course should support the emergence of results that will become part of the masters degree project. The practice is usually carried out at the supervisor's workplace.</td></tr>
<tr><td>01FAN3</td><td>Functional Analysis 3</td><td>Z,ZK</td><td>5</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>01FIMA</td><td>Financial and Insurance Mathematics</td><td>ZK</td><td>2</td></tr>
<tr><td colspan="4">This course is an introduction to the problems of life and non-life insurance and financial mathematics.</td></tr>
<tr><td>01KOS</td><td>Compressed Sensing</td><td>ZK</td><td>2</td></tr>
<tr><td colspan="4">The lecture will introduce basic concepts of the theory of compressed sensing an area founded in 2006 in the works of D. Donoho, E. Candes, and T. Tao. This theory studies the search for sparse solutions of underdetermined systems of linear equations. Due to the applications of sparse representations in electric engeneering and signal processing, this theory was quickly used in many different fields. After the first survey lecture, we will study the mathematical foundations of the theory. We prove general NP-completeness of the search for sparse solutions of systems of linear equations. We introduce conditions which ensure also existence of more effective solvers and show, that these are satisfied for example for Gaussian random matrices. As an effective solution method, we will analyze l1-minimization and Orthogonal Matching Pursuit. We will also study stability and robustness of the obtained results with respect to the corruption of measurements and the optimality of the results.</td></tr>
<tr><td>01LBM</td><td>Lattice Boltzmann Method</td><td>KZ</td><td>2</td></tr>
<tr><td colspan="4">The lattice Boltzmann method (LBM) is a modern numerical method allowing the solution of non-stationary partial differential equations by solving the Boltzmann transport equation for unknown densities of the particle probability distribution function. The course introduces the basics of the LBM theory, derived equivalent partial differential equations for an advection-diffusion problem and for the incompressible Newtonian flluid flow, and the basic properties of the numerical scheme are derived. The exercises are then devoted to the practical implementation and computations of LBM using the computational infrastructure at FNSPE CTU in Prague, especially with the focus on GPU computing.</td></tr>
<tr><td>01MAL</td><td>Mathematical Logic</td><td>Z,ZK</td><td>4</td></tr>
<tr><td colspan="4">Logic is in the same time an object studied by mathematics and the language used to formalize and study mathematics. The goal of the course is to introduce basic notion of results of classical mathematical logic. 1.Propositions, evaluation, tautologies, axioms, theorems, soundness, completeness, and decidability of Hilbert and Gentzen style propositional calculi. 2.Language of predicate calculus, terms, formulas, relational structures, satisfiability, truth, tautologies, axioms, theorems, soundness, model constructions. 3.Gödel completeness theorem, Skolem and Herbrand theorems. 4.The first and the second Gödel theorems on incompleteness of Peano arithmetics and undecidability of predicate calculus.</td></tr>
<tr><td>01MBM</td><td>Mathematical techniques in biology and medicine</td><td>Z,ZK</td><td>3</td></tr>
<tr><td colspan="4">Spatially independent models; enzyme kinetics; excitable system; reaction-diffusion equations; travelling waves; pattern formation; conditions for Turing instability, the effect of domain size; the concept of stability in PDEs, spectrum of a linear operator, semigroups.</td></tr>
<tr><td>01MKP</td><td>Finite Element Method</td><td>ZK</td><td>3</td></tr>
<tr><td colspan="4">The course is devoted to the mathematical theory of the finite element method numerically solving boundary-value and initial-boundary-value problems for partial differential equations. Mathematical properties of the method are explained. The approximation error estimates are derived.</td></tr>
<tr><td>01MMDY</td><td>Mathematical Methods in Fluid Dynamics 1</td><td>ZK</td><td>2</td></tr>
<tr><td colspan="4">First, the differential equations representing the conservation laws of fluid flow are briefly derived and reviewed. Next, the problems for the resulting equations are formulated, focusing on boundary conditions specification. The reference problem undergoes numerical analysis with emphasis on explaining the weak solution and its role in describing real phenomena. In the second part, important problems are introduced, involving fluid flow and other effects (heat transfer, chemical reactions, multiphase nature) and an adequate mathematical description is chosen.</td></tr>
<tr><td>01MMNS</td><td>Mathematical Modelling of Non-linear Systems</td><td>ZK</td><td>3</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>01MRMMI</td><td>Methods for Sparse Matrices</td><td>KZ</td><td>2</td></tr>
<tr><td colspan="4">The course is aimed at utilization of sparse matrices in direct methods for solution of large systems of linear algebraic equations. The course will cover the decomposition theory for symmetric and positive definite matrices. Theoretic results will be further applied for solution of more general systems. Main features of the methods and common implementation issues will be covered.</td></tr>
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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.			
01NELO	Nonlinear Optimization	ZK	4
Nonlinear optimization problems find their application in may areas of applied mathematics. The lecture covers the basics of mathematical programming theory with emphasis on convex optimization and basic methods for unconstrained and constrained optimization. The lecture is supplemented by illustrative examples.			
01NMDT	Numerical Methods in Fluid Dynamics	ZK	2
The course is focused on the design and properties of numerical methods for solving fluid flow equations. Focus is put mainly on the finite volume method whose classical and advanced schemes are derived. Selected schemes are analyzed in terms of stability. The second part is devoted to advanced numerical schemes used in practice. The matter is concluded by a brief summary of alternative numerical approaches for fluid flow simulation and by a demonstration of visualization techniques for simulation results.			
01PAA	Parallel Algorithms and Architectures	KZ	4
This course deals with the parallel data processing. It is important in situations when one processing unit (CPU) is not powerful enough to finish given task in reasonable time. When designing parallel algorithms, good knowledge of the parallel architectures is important. Therefore these architectures are studied as a part of this course too.			
01PALG	Advanced Algorithmization	KZ	2
Keywords: String algorithms, graph algorithms, dynamic programming, suffix tress, graph cuts, numerical methods for solution of partial differential equations.			
01PAMF	Mainframe Programming in Assembler	Z	2
In this course the basics of programming in z/OS are explained namely the programming in assembler. Basic instructions, macros, I/O operations, DLL library loading and some other topics are discussed.			
01PDE	Modern theory of partial differential equations	Z,ZK	4
1. Sobolev spaces. 2. Definition, completeness, examples. 3. Continuous and compact embedding theorems. 4. Trace theorem. 5. Weak solution (importance, derivation of the weak formulation). 6. Elliptic PDE of Second Order. 7. Existence and uniqueness of weak solutions (Lax-Milgram theorem). 8. Regularity of weak solutions. 9. Relation to the calculus of variations, Poincaré inequality. 10. Maximum principle for classical and weak solutions.			
01PNL	Advanced Methods of Numerical Linear Algebra	ZK	2
Representation of real numbers in computers, behaviour of rounding errors during numerical computations, sensitivity of a problem, numerical stability of an algorithm. We will analyse sensitivity of the eigenvalues of a given matrix and sensitivity of roots of systems of linear algebraic equations. Then, the backward analysis of these problems will be performed. The second part of the course is devoted to the methods of QR-decomposition, least squares problem, and to several modern Krylov subspace methods for the solution of systems of linear algebraic equations and the Lanczos method for approximation of the eigenvalues of a symmetric square matrix.			
01SDR	Stochastic Differential Equations	ZK	2
The class is devoted to an introduction to stochastic differential equations and their applications. The content includes stochastic processes, Itô integral and solution of stochastic differential equations. The applications in filtering, diffusion and optimal control are mentioned as well.			
01SKE	System Reliability and Clinical Experiments	KZ	3
The main goal of the subject is to provide the mathematical principles of reliability theory and techniques of survival data analysis, reliability of component systems, asymptotic methods for reliability, concept of experiments under censoring and their processing in clinical trials (life-time models). The techniques are illustrated and tested within practical examples originating from lifetime material experiments and clinical trials.			
01SMF	Modern Trends in Corporate Information Technologies	Z	2
The course is devoted to mainframe administration basics. After introduction to mainframe hardware the following lectures covers security, transaction systems, virtualization and non-relational databases in the mainframe environment.			
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.			
01SUP	Start-up Project	KZ	2
01SVK	Student's Scientific Conference	Z	1
This is the active participation of the student in one of the approved student conferences. The list of such conferences is defined by the course guarantor.			
01TEC	Number Theory	ZK	5
1. Algebraic and transcendental numbers 2. Algebraic number fields, field isomorphisms 3. Rational approximations, continued fractions 4. Diophantic equations, Pell's equation 5. Rings of integers in algebraic number fields and divisibility 6. Number representation in non-integer bases, finite and periodic expansions			
01TEMA	Matrix Theory	Z	3
The subject deals mainly with: 1) similarity of matrices and canonical forms of matrices 2) Perron-Frobenius theory and its applications 3) tensor product 4) Hermitian and positive semidefinite matrices			
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.			
01TIN	Information Theory	ZK	2
Information theory explores the fundamental limits of the representation and transmission of information. We will focus on the definition and implications of (information) entropy, the source coding theorem, and the channel coding theorem. These concepts provide a vital background for researchers in the areas of data compression, signal processing, controls, and pattern recognition.			
01UMF	Introduction to Mainframe	Z	2
In this course we teach the mainframe architecture. We explain how to operate the system z/OS, how to start a job using the JCL and we explain some differences when programming in C/C++ for z/OS:			
01URG	Introduction to Riemannian geometry	ZK	2
This lecture is intended for an advanced undergraduate having possibly (but not necessarily) already taken a basic course on topological and differential manifolds. In addition to understanding the geometric meaning of curvature and its intimate relationship to topology, the student will learn the basic apparatus of Riemannian geometry suitable for further study of modern parts of mathematics and mathematical physics. Possible extension of this lecture is the geometric analysis of partial differential equations on Riemannian manifolds.			
01UTS	Introduction to the Theory of Semigroups	ZK	3
It is known that a system of linear ordinary differential equations can be solved by virtue of the matrix exponential. However, the extension to partial differential equations is not straightforward. For example in the case of heat equation the matrix is replaced by Laplace operator which is not bounded and the series for the exponential will not converge. Moreover,			

solutions of the heat equation exist in general only for positive times and hence the solution operator can be at best a semigroup. The aim of the course is to provide a mathematical foundation for these types of problems and extend the concept of stability from ordinary differential equations, which is again in relation to spectrum of a linear operator.			
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.			
01VUMM1	Research Project 1	Z	6
Research project on the selected topic under the supervision. Supervision and regular checking of the research project under preparation.			
01VUMM2	Research Project 2	KZ	8
Research project on the selected topic under the supervision. Supervision and regular checking of the research project under preparation.			
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.			
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.			
12DRP	Differential Equations on Computer	Z,ZK	5
Ordinary differential equations, analytical methods; Ordinary differential equations, numerical methods, Runge-Kutta methods, stability; Partial differential equations, analysis, hyperbolik, parabolic and elliptic equations, posedness of differential equaitons; Partial differential equations, numerical solution, finite difference methods, difference schemes, order of approximation, stability, convergence, modified equation, diffusion, dispersion; Conservation laws and their numerical solution, shallow water equations, Euler equations, Lagrangian methods, ALE methods; Practical computation in Matlab system for numerics and Maple for analysis of schemes.			
18HA	Heuristic Algorithms	ZK	4
Heuristic algorithms of optimization operates on discrete or continuous domains. Brutal force, stochastic, greedy, physically, biologically and sociologically motivated heuristic are included, used for optimum finding and compared.			
18MEMC	Monte Carlo Method	Z,ZK	4
This courseis devoted to the numerical method Monte Carlo and to its selected applications.			
18OOP	Object Oriented Programming	Z	2
This course consists of the contributions of students concerning given topics concerned on technologies uded in program development.			
18PCP	Advanced C++	Z,ZK	4
This lecture covers the virtual inheritance,variadic templetes, template metaprogramming, template libraries design and implementation, tools for data type processing in compile time and for the advanced diagnostic of the templates, concepts, coroutines, modules, ranges, views and other tools introduced in C++ 20, application of the multithreading (execution parallelization).			

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