ENTRANCE EXAMINATION PROGRAM

FOR PHYSTECH SCHOOL OF APPLIED MATHEMATICS AND INFORMATICS
COMPUTER SCIENCES AND INFORMATICS
COMPETITIVE GROUP

FOR APPLICANTS ENTERING PHD PROGRAMS

At the entrance examination applicants will be asked questions on their final qualifying work and questions from the section corresponding to specialty of their future research activity.

Questions on the final qualifying work (master or specialist's degree):

1. Main provisions.
2. Novelty.
3. Relevance.

Sections corresponding to the specialty of future research activity

Mathematical analysis

1. Limits of a sequence. Cauchy criterion. Existence of a limit for a monotonically increasing sequence bounded above. The Bolzano-Weierstrass theorem on the existence of a convergent subsequence of a bounded sequence.
2. Number series. Cauchy criterion. Convergence tests (comparison tests, d'Alembert's ratio test, Leibniz's theorem, Dirichlet's test).
3. Limit of a function. Continuous functions. Properties of continuous functions on an interval (Weierstrass's theorems on the boundedness and attainability of the upper and lower bounds. Cauchy's intermediate value theorem). Generalizations of multidimensional case. Existence of one-sided limits for monotone functions. Theorem on the continuity of an inverse function and a continuous monotone one. Uniform continuity.
4. Differentiable functions of one and several variables. Derivatives and differential. Taylor’s theorem for functions (one and several variables). Taylor series. Elementary functions. Implicit function theorem (without proof).
5. Calculation of limits using the Taylor’s theorem. Sufficient conditions for the monotonicity of a differentiable function. Convex functions. Sufficient conditions for the convexity of a function twice differentiable on an interval. Asymptotes.
6. Extrema of functions of one and several variables. Necessary conditions for an extremum. Sufficient extremum conditions for differentiable functions.
7. Riemann integral. Necessary and sufficient conditions for Riemann integrability of a function. The mean value theorem. Leibniz-Newton formula for antiderivative. The formula for integration by parts. Improper integrals. Convergence tests of improper integrals. Dirichlet’s test.
8. The concept of a multiple integral according to Riemann. Reduction of a multiple integral to an iterated one. Change of variables in multiple integrals.
9. The concept of a smooth curve, a smooth surface, their parametric assignment. Determining the length of a curve, the area of a piece of surface. Curvilinear integrals of the first and second kind. Surface integrals of the first and second kind.
10. Green's theorem in the plane. Gauss-Ostrogradsky theorem. Stokes theorem. Differential operations. Gradient, divergence, curl (vortex). Curvilinear integrals independent of the

path integration. Potential vector fields. Total differential, necessary conditions, sufficient conditions.

11. Functional sequences and series. Uniform convergence. Cauchy's convergence test. Weierstrass test for uniform convergence of continuous functions. Theorems on term-by - term integration and differentiation of functional series.
12. Integrals depending on a parameter. Uniform convergence of an improper integral depending on a parameter. Theorems on the continuity and differentiability of integrals depending on a parameter.
13. Fourier series in the trigonometric system. Convergence of Fourier series for piecewise smooth functions. Decreasing order of the Fourier coefficients for an l-times continuously differentiable function. Uniform convergence of the Fourier series for a continuously differentiable function. Uniform approximation of continuous functions on a segment by trigonometric polynomials.
14. Minimal property of Fourier coefficients. Bessel's inequality and Parseval's identity. The concept of Hilbert space and abstract Fourier series in terms of a complete orthonormal system. Theorem on the convergence and mean of Fourier series in the trigonometric system for a function that is integrable.
15. Fourier transforms. Treatment formula. Fourier transform of the derivative and derivative of the Fourier transform.

Linear algebra

1.The concept of a linear space. Definition of linear dependence and independence of vectors. The dimension of a linear space. Basis, vector coordinates, coordinate transformation equations when moving from one basis to another.

2.Matrices and actions on them. Determinant of a square matrix. Matrix rank. The equivalence of its two definitions in terms of the linear independence of the rows (or columns) of the matrix and in terms of the inequality of minors to zero.

3.Systems of linear algebraic equations. Solution of a homogeneous system. Solution of an inhomogeneous system of linear equations. Kronecker-Capelli compatibility criterion.

4.Linear transformations in n-dimensional space. Linear transformation matrix and its meaning. Changing the linear transformation matrix when changing the basis. The range of the linear transformation and its matrix. Product of linear transformations.

5.Eigenvectors and eigenvalues of linear transformations. Characteristic polynomial. Linear independence of eigenvectors corresponding to different eigenvalues. Linear transformation matrix in the basis of eigenvectors. Jordan basis of linear transformation and Jordan normal form (without proof).

6.Dot product in Euclidean space. Coordinate representation of the dot product. Orthonormal basis. orthogonalization process.

7.The concept of a self-adjoint linear transformation. Properties of its eigenvalues and eigenvectors. Self-adjoint transformation matrix.

8.Orthogonal transformations. Orthogonal transformation matrix. Orthogonal matrices. Transition from one orthogonal basis to another.

9.Bilinear and quadratic forms. Their matrices and formulas for the transition from one basis to another. Carrying out a quadratic form to a canonical form in an orthonormal basis. Law of inertia for quadratic forms. The concept of a positive definite quadratic form. Sylvester's criterion (without proof).

Ordinary differential equations

1.Elementary methods for integrating first-order equations (equations with separating variables, homogeneous equations, linear equations, Bernoulli equations, equations in total differentials).

2.Existence and uniqueness theorems for the solution of the Cauchy problem for one 1st order equation and for a system of n 1st order equations with n unknowns in normal form (without proof). Specificity of the case of linear differential equations.
3.Linear equations of the nth order with constant coefficients. Solution of a homogeneous equation. Solution of an inhomogeneous equation with a special right-hand side in the form of a quasi-polynomial. Euler equation.
4.Solution of a homogeneous first order system with constant coefficients (the case of simple roots).
5.Linear equations of the nth order with variable coefficients. Fundamental system of solutions of a homogeneous equation and its existence. Wronskian. Liouville's formula. Possibility of lowering the order of a homogeneous equation. Solution of a homogeneous equation. Solution of an inhomogeneous equation. Method of variations of arbitrary constants.
6.Systems of linear equations of the first order with variable coefficients. Fundamental system of solutions of a homogeneous system and its existence. Liouville formula. The method of variation of arbitrary constants in finding a particular solution of an inhomogeneous system. The structure of the general solution.
7.The concept of equations that are not resolved with respect to the highest derivative. Special solution.
8.Autonomous systems. Equilibrium position. Phase plane and phase trajectories. Classification of equilibrium positions in the plane. The concept of stability of an equilibrium position according to Lyapunov and asymptotic stability. Theory of stability in linear approximation.
9.The first integrals of an autonomous system. Linear homogeneous equations in partial derivatives of the first order. General view of the solution. Cauchy problem. The concept of characteristics.
Elements of the calculus of variations. 10.The simplest problem of the calculus of variations and its simple generalizations. Constrained variational problem, isoperimetric problem.

Theory of functions of a complex variable
1.Function of one complex variable. Differentiable functions of a complex variable. Cauchy-Riemann equations. The geometric meaning of the modulus and argument of the derivative of a function of a complex variable.
2.Equality to zero of the integral of a differentiable function over a closed contour contracting to a point. Cauchy's integral formula.
3.The concept of a regular function at a point and in a region. Power series. Abel's first theorem. The circle of convergence of a power series. Term by term differentiation and integration of power series. Equivalence of differentiability and regularity of function and domain. Regularity of uniformly convergent series and regular functions.
4.Expansion in a Taylor series of a function differentiable in a neighborhood of a point.
Laurent series. Elementary Functions Z^n, e^Z, *Sin Z*, *Cos Z*, *Sh Z*, *Ch Z*, etc.
5.Isolated Singular Points of Single Character. Classification: removable singular point, pole, essential singular point. Characterization of the singular point of a function in terms of the coefficients of the Laurent series.
6.The concept of a residue at an isolated singular point of a single-valued nature. Calculation of contour integrals using residues.
7.Decomposition of meromorphic functions into elementary fractions. Infinite products. Examples of decomposition of some entire functions into infinite products.
8.The uniqueness theorem for a regular function taking given values on a sequence of points, the limit of which is contained in the domain of regularity. Analytic continuation. The concept of a complete analytic function. Main multivalued elementary functions _____ ln Z. The concept of a Riemann surface

9.Conformal mappings implemented by regular functions. The concept of a univalent mapping. Fractional linear mappings and their properties. Mappings carried out with the help of some elementary functions. Riemann's general theorem on the existence of conformal mappings (without proof). The principle of correspondence of boundaries under conformal mapping.

Equations of Mathematical Physics

1.Linear differential equations in partial derivatives of the 2nd order. Reduction to canonical form at a point. Classification of equations. Elliptic, hyperbolic and parabolic equations.
2.Linear differential equations of the 2nd order in the plane. The concept of characteristics. Reduction to the canonical form in the domain. Cauchy problems. Cauchy-Kovalevskaya theorem (without proof).
3.The concept of a well-posed boundary value problem for a partial differential equation. Examples of some problems (Cauchy problems for the Laplace equation). Statement of classical problems of mathematical physics and their physical meaning (the Cauchy problem and the mixed problem for the string vibration equation, for the heat equation, the Dirichlet and Neumann boundary condition for the Laplace equation).
5.Fredholm integral equations. Integral equations with degenerate kernel. Fredholm's theorem for Fredholm integral equations of the second kind with a continuous kernel (without proof). Generalization to the case of polar nuclei. The method of successive approximations and the Neumann series.
6.The Sturm-Liouville theory. Green's function of a boundary value problem for an ordinary differential equation. Reduction of the Sturm-Liouville theory to an integral equation. Properties of eigenvalues and eigenfunctions of the Sturm-Liouville theory.
7.Cauchy problem for the wave equation. D'Alembert's formula in the case of the string vibration equation. Existence and uniqueness of a solution. The area of dependence of the solution on the initial data.
8.Mixed problems for hyperbolic equations. Fourier method (method of separation of variables). Uniqueness of the solution.
9.The Cauchy problem for the heat equation. The existence and uniqueness theorem. Poisson formula. Fundamental solution and its meaning.
10.Mixed problem for the heat equation. Fourier method (method of separation of variables). Uniqueness of solution, maximum principle.
11.Laplace and Poisson equations. Harmonic functions and their properties. Green's formulas. The mean value theorem for harmonic functions. Principle of maximum and minimum for harmonic functions.
12.The Dirichlet problem for the Laplace equation. Fundamental solution. The concept of Green's function for the Dirichlet problem. Solution of the Dirichlet problem for the Laplace equation in a circle
Fourier method. Existence and uniqueness of a solution to the Dirichlet problem in the general case (without proof).
13.The Neumann problem for the Laplace and Poisson equations. Necessary and sufficient conditions for its solvability. Degree of decision uncertainty.

References

Mathematical analysis

1. Кудрявцев Л.Д. Курс математического анализа, т. 1 и т. 2.
2. Никольский С.М. Курс математического анализа, т. 1 и т. 2.
3. Фихтенгольц Г.М. Курс дифференициального и интегрального исчисления, т. 1, т. 2 и т. 3.
4. Смирнов В.И. Курс высшей математики, т. 1 и т. 2.

Linear algebra

1. Беклемишев Д.В. Курс аналитической геометрии и линейной алгебры.
2. Гельфонд И.М. Лекции по линейной алгебре.
3. Курош Л.Г. Курс высшей алгебры.

Ordinary differential equations

1. Федорюк М.В. Обыкновенные дифференциальные уравнения.
2. Степанов В.В. Курс дифференциальных уравнений.
3. Петровский И.Г. Лекции по теории обыкновенных дифференциальных уравнений.
4. Понтрягин Л.С. Обыкновенные дифференциальные уравнения.
5. Смирнов В.И. Курс высшей математики, т. 2.

Theory of functions of a complex variable

1. Сидоров Ю.В., Федорюк М.В., Шабунин М.И., Лекции по теории функций комплексногопеременного.
2. Лаврентьев М.А., Шабат Б.В. Методы теории функций комплексного переменного.
3. Привалов И.И. Введение в теорию функций комплексного переменного.
4. Маркушевич А.И. Теория аналитических функций т. 1. и т. 2.

Equations of Mathematical Physics

1. Тихонов В.Н., Самарский А.А. Уравнения математической физики.
2. Петровский И.Г. Лекции об уравнениях с частными производными.
3. Владимиров В.С. Уравнения математической физики.
4. Смирнов В.И. Курс высшей математики т. 2 и т. 4.

Computational Mathematics

1.Solution of systems of nonlinear equations. Newton's method. Theorem on the quadratic rate of convergence. Simple iteration methods, convergence analysis. Parameter continuation method.
2.Numerical differentiation. Basic difference approximations of the first and second derivatives. Approximation error, rounding error. The optimal step of numerical differentiation.
3.Numerical integration of the Cauchy problem for ODE systems. Grid method, simplest difference schemes (Explicit and implicit Euler schemes, central differencing scheme). Implementation of difference schemes. Approximation error, grid spacing criteria.
4.Methods of Runge-Kutta type, basic construction, implementation algorithm. Problem of convergence method. Stability of Runge-Kutta methods. Convergence theorems under different proposals for the matrix fx(x).
5.ODEs stiff equations. Numerical methods of solution. A - stable, A(α) - stable methods. Asymptotic stability.
6.Boundary value problems for ODE systems. Statement of a general (multipoint) boundary value problem. Linear boundary value problems, their solution of the problem to the fundamental solution system. Reduction of a linear boundary value problem to Cauchy problems.
7.Nonlinear boundary value problems for ODE systems. Shooting method, quasi-linearization method (like Newton's method in functional space).
8.Linear boundary value problems with a large parameter. Computational instability of the simplest reduction to Cauchy problems. Sweeping method. Equation for sweep coefficients. Reductions to stable Cauchy problems.
9.Sweeping in the Sturm-Liouville difference problem. Difference sweeping algorithm, recurrent formula.
10.Mesh method for the heat equation. The simplest difference schemes (explicit, implicit). Approximation of equations, initial and boundary conditions. Explicit schema implementation.

Layer count. Implementation of the implicit scheme, the equation on the upper layer, its solution by the sweeping method.
11.Nonlinear equations, their difference approximation and implementation of the corresponding schemes. Schemes with non-linearity on the upper layer, their implementation (Newton's method and sweeping method).
12.Stability of difference schemes as a continuous dependence of the solution on the input information. Spectral stability. Spectrum calculation technique. The practice of applying the spectral stability. The principle of frozen coefficients. Spectral stability and stability according to initial data. Stability of boundary conditions.
13.Two-dimensional heat conduction equation. Explicit and implicit schemes. The problem of solving equations in the upper layer. Method of variable directions. Its implementation, the cost-effectiveness of the method. Spectral stability. Method of variable directions in three-dimensional problems. Schemes with a factorized regularizer. Spectral stability of such schemes. Splitting method, circuits with an excluded intermediate layer.
14.Solutions of the Poisson equations by the grid method. Difference approximation of the Poisson equations. Method of simple iterations, error, discrepancy. Spectrum of the Poisson difference problem, eigenvalues and functions. Spectral analysis of the convergence of simple iterations. Choice of the optimal iterative parameter. Estimation of the number of iterations. Chebyshev acceleration method for simple iterations. Stability analysis. Stable renumbering of iterative parameters.
15.The method of variable directions for solving the Poisson difference equation. Spectral analysis of convergence. Choice of the optimal iterative parameter. Estimation of the number of iterations. Method of alternating directions with a series of parameters.
16.Numerical methods for solving problems of continuum mechanics. The idea of constructing difference schemes. Conservative methods.
17.Methods for searching for extrema of functions
18.Ill-posed tasks. Examples. Qualitative description of the approach to their solution. The role of a priori information. Examples - integral equation of the 1st kind. The inverse problem of heat conduction.
19.The main idea of regulation. A priori information. Mathematical formalism. The role of choosing the norm in the concept of incorrectness. natural norms. Tikhonov correctness set. Theorem on the continuity of the inverse mapping on the image of a compact. Compact as a mathematical equivalent of a priori information. Quasi-solution approach. Theorem on the continuity of the quasi-solution.

Reference

1. В.С. Рябенький. Введение в вычислительную математику. М.: Физматлит, 2009г., 294с.
2. Р.П. Федоренко. Введение в вычислительную физику. Долгопрудный. Издательский домИнтеллект, 2000г., 503с.
3. Н.Бахвалов, Н. Жидков, Г. Кобельков. Численные методы. М.-СПб: Физматлит, 2000г.,622с.
4. И.Б. Петров, А.И. Лобанов. Лекции по вычислительной математике. 2006г., 522с.

Algorithms

1. The concept of an algorithm.
2. The concept of the spatial complexity of an algorithm.
3. The concept of time complexity of an algorithm.
4. Turing machine.
5. Post machine.

6. Markov algorithm.
7. Halting problem.
8. Sorting algorithms.
9. Greedy algorithm.
10. Binary search.
11. Dynamic programming (2, 3-dimensional).
12. Dynamic programming by subsegments.
13. Dynamic programming with profile.
14. Discrete and continuous knapsack problem.
15. Least common ancestor problem (Least Common Ancestor, LCA).
16. Complexity classes of algorithms (P, NP).
17. Prefix function
18. Z-function. Knuth-Morris-Pratt algorithm.
19. Aho-Corasick algorithm.
20. Extended Euclidean algorithm.
21. Sieve of Eratosthenes.
22. Lossless data compression algorithm.
23. Euclidean algorithm.
24. Sieve of Eratosthenes.
25. Computational complexity of algorithms for addition, multiplication, raising to an integer power.
26. Asymptotic law for the distribution of prime numbers. Algorithms for checking numbers for simplicity.

Reference

1. Мальцев А. «Алгоритмы и рекурсивные функции», М.: Наука, 1985 г.
2. Винокуров В. А., Ворожцов А. В. «Практика и теория программирования», М.: Физматкнига, 2008.

Procedural programming

1. Basic algorithmic constructions: conditional operator (if), multiple choice operator (case/switch/select), loops with precondition and postcondition (for/while/until), transition operator (go to).
2. Dividing programs into procedures and modules. The concept of the stack and its use. Global and local variables, the concept of scope. Top-down approach in programming.
3. Basic types and data structures: numbers, enumerations, strings, sets, arrays, record/struct. The principle of "programs = algorithms + data structures".
4. The concept of structured programming, Dijkstra’s algorithm.

Reference

1. Дейкстра Э. «Дисциплина программирования», пер. с англ., М.: Мир, 1978 г.
2. Вирт Н. «Алгоритмы + структуры данных = программы», пер. с англ., М.: Мир, 1985 г.
3. Холл П. «Вычислительные структуры», пер. с англ. М.: Мир, 1978 г.

Data Structures

1.Stack

2.Queue
3.Priority queue
4. Decks
5. Singly linked lists.
6. Doubly linked lists.
7. Heap.
8. Binary tree.
9. Cartesian tree.
10. Hash tables.
11. Binary container (Range Minimum Query, RMQ), description and application examples.
12. Segment tree.
13. Fenwick tree.
14. Red-black tree.
15. The concept of a map. Implementation of maps through binary trees and hash tables.

Reference

1. Кнут Д. Э. «Искусство программирования для ЭВМ», в 7-ми томах, тома 1,2,3, пер. с англ.,М.: Мир, 1976 г.
2. Холл П. «Вычислительные структуры», пер. с англ., М.: Мир, 1978 г.

C++ programming language

1. Preprocessor.
2. Branches
3. Cycles
4. Functions
5. Arrays
6. Pointer arithmetic
7. Recursion.
8. Structures.
9. Union.
10. C standard library.
11. STL library.
12. Boost libraries.
13. C++11, C++14 standards.

Reference

1. Керниган Б., Ритчи Д. «Язык программирования Си», 2-е издание, пер. с англ., М.: Финансы и статистика, 1992 г.
2. Страуструп Б. «Язык программирования C++», 3-е издание, пер. с англ., СПб.: Невскийдиалект, 1999 г.

Java programming language

1. Java virtual machine.
2. Memory management.
3. Passing primitive types to functions.

4. Passing reference types to functions.
5. The problem of changing the link inside the subroutine.
6. Static initializers.
7. Removal of unused objects and the finalize method.
8. The problem of destructors for complex objects.
9. Garbage collection.

Reference

1.Программирование на Java Автор: Вязовик Н.А. М., «Интуит», 2003

Computer architecture

1.Computer architecture (Harvard, von Neumann)
2. Processor instruction set (CISC, RISC, VLIW)
3. Cache and acceleration of work with its use.
4. Calling conventions. Conventions cdecl, fastcall, stdcall.
5. Representation of integers. Additional code.
6. Representation of floating-point numbers.
7. Assembly language.
8. Execution of commands in pipeline. Conditional execution of commands.
9. Debugging and instrumentation tools (valgrind, AddressSanitizer, strace, gdb)
10. Static and dynamic libraries.
11. The concept of program profiling.
12. Static method for studying programs. Recovery of algorithms and data structures.
13. Dynamic method of studying programs. Basic principles of functioning of the debugger. Beacon method and tracing method.
14. Protection against disassembly and debugging. Embedding protective services in the software.
16. Basic methods of technical protection against unauthorized copy programs and data. Identification of computer parameters. Electronic keys.

Reference

1. Брайант Р., О`Халларон Д. Компьютерные системы: архитектура и программирование. Взгляд программиста. “БХВ-Петербург”, 2005, ISBN 5-94157-433-9

Principles of building modern operating systems

1. Classification of operating systems.
2. Real-time operating systems.
3. The concept of the process, types of processes.
4. Files. The structure of the file system.
2. Memory management: single allocation, page, segment, segment-page, swapping.
3. Interaction of processes, IPC: pipes, signals, message queues, sockets, semaphores, shared memory.
5. Types of virtualization.
6. Ways to share resources. Deadlock prevention. Communication between processes through messages and shared memory.
7. The concept of a message queue. Event driven programming. Models of asynchronous process control, Petri nets.
8. File system. The concepts of file and directory. Synonyms and references, their purpose. Network file systems.
9. Security systems. The concept of a user account, user groups. Purpose of logs.

10. The concept of identification and authentication. Authentication methods and schemes. Information required for authentication.
11. Classification of security threats. Typical architecture of the OS protection subsystem. Access control: basic concepts.
12. Access control model. The main functions of the access control system. Access control schemes (access lists, mandate scheme, access labels, context-sensitive scheme). Information required for access control. Implementation of access control on the example of rights in UNIX-like operating systems. SELinux, AppArmor.

Reference

1. Немет Э., Снайдер Г., Сибасс С., Хейн Т. «UNIX: Руководство системногоадминистратора», пер. с англ., К.: BHV, 1996 г.
2. Дженнигс Р. «Windows 95 в подлиннике», пер. с англ., СПб.: BHV-Санкт-Петербург, 1995 г.
3. «Сетевые средства Microsoft Windows NT Server 4.0», пер. с англ., СПб.: BHV-Санкт-Петербург, 1999 г.
4. Колин А. «Введение в операционные системы», пер. с англ., М.: Мир, 1975 г.
5. Цикритзис Д. и др. «Операционные системы», пер. с англ., М.: Мир, 1977 г.
6. Карпов В. Е., Коньков К. А. «Основы операционных систем», М.:Интернет-университетинформацонных технологий, 2005.

Object-oriented programming.

1. Object = data + methods for working with them. Abstraction as a means of modeling reality with the help of objects.
2. Encapsulation. Modification and optimization of programs using encapsulation.
3. Inheritance. Code reuse. Polymorphism as a means of ensuring the extensibility of programs.
4. The concept of properties and events in object technologies. Persistence of objects. The concept of an interface as an alternative means of providing polymorphism.
5. Class diagrams. The concept of object-oriented design.
6. Templates and their use.
7. Handling emergency situations. The concept of exclusion. Stack unwinding in exception handling. Exception Handling.

Reference

1. Буч Г. «Объектно-ориентированный анализ и проектирование с примерами приложений на C++», 2-е издание, пер. с англ., М.: Издательство Бином, СПб.: Невский диалект, 1999 г.
2. Роджерсон Д. «Основы COM», пер. с англ., М.: Русская редакция: Channel Trading Ltd,1997 г.

Network technologies

1. Client-server concept. Examples of its application.
2. The concept of the architecture of distributed computing systems. Computer networks. Seven-layer model of open systems interaction (OSI Seven - Layer Model).
3. Structure, topology and architecture of computer networks. Reference model of open systems interaction. Internet architecture. LAN architecture. Routing and flow control in computer networks.
4. IPv4 protocol. The concept of IP address, subnet mask. IPv6 protocol.
5. System calls for network support in the OS (socket, bind, listen, access, connect, read, write, send, recy, ...)

6. TCP and UDP protocols.
7. Serialization/deserialization.
8. Basics of the HTML language. Main tags.
9. Domain name system.
10. The concept of network latency, RTT.
11. Remote procedure call.
12. Principles of organization of e-mail and the World Wide Web.
13. Application layer protocols.
14. The thin-client architecture, its advantages and disadvantages.
15. Definition, structure and functioning of firewalls. Blocking and allowing firewalls. What can and can't firewalls protect against? DMZ concept. Unauthorized data exchange. Ways to bypass firewalls. Legislation of the Russian Federation in the field of site blocking.
16. Attacks and crashes. The point of failure of the entire system. Building fault-tolerant systems.
17. COM/DCOM and CORBA technologies as a language-independent means of organizing interaction between applications and code reuse.

Reference

1. Роджерсон Д. «Основы COM», пер. с англ., М.: Русская редакция: Channel Trading Ltd, 1997 г.
2. Орфали Р., Харки Д., Эдвардс Д. «Основы Corba», пер. с англ., М.: Малип, 1999 г.

Computer graphics.

1. Representation of color in a computer.
2. Graphic formats.
3. Vector and raster formats.
4. Projections.
5. Marching cubes method.
6. Fast Fourier transform.
7. Data compression with loss of quality.
8. Graphical user interface.

Artificial intelligence

1. Machine learning. The concept of training and control samples.
2. Neural networks.
3. 3 laws of robotics.
4. The use of graphics accelerators in machine learning.

Methods for data analysis and recognition

1. The problem of recognition.
2. The problem of classification.
3. The concept of errors of the first and second kind.

Graph theory.

1. Vertices and edges.

2. Directed and undirected graphs.
3. Adjacency matrix.
4. Incidence matrix.
5. Tree.
6. Cayley's formula (number of spanning trees in a complete graph).
7. Bypass in depth.
8. Bypass in width.
9. Flow in a graph.
10. Routes, chains, cycles.
11. Euler path.
12. Hamiltonian path.
13. Floyd's algorithm.
14. Dijkstra's algorithm.
15. Kruskal's algorithm.
16. Dinic's algorithm.
17. Bipartite graphs. Matching.
18. Planarity of a graph.

Reference

1. Т. Кормен, Ч. Лейзерсон, Р. Ривест. «Алгоритмы: построение и анализ». М.: МЦНМО, 2000.

Database

1. DBMS. Logical and physical data structure. Means of ensuring data integrity. Transactions.
2. Relational data model. Data normalization. ER - diagrams. SQL language.
3. Client-server and three-level architectures for working with databases. The purpose of the intermediate layer.
4. Data storage. Comparison with operational databases. Denormalization. Multidimensional data model. OLAP. Data marts. Their use as an intermediate layer in a three-tier architecture.
5. The concept of database security. Database security threats: general and specific. Interpretation of security aspects for the database: confidentiality, integrity, availability.
6. Access control to the database. Main concepts: subjects and objects, user groups, privileges, roles and views. Types of privileges: system and object. Use of user roles and privileges.
7. Using transactions and locks to ensure the integrity of data in the database. Committing and rolling back a transaction. Types of locks.
8. Referential integrity. Declarative and procedural referential integrity. External key. Ways to maintain referential integrity.
9. SQL injections.

Reference

1. Мартин Дж. «Организация баз данных в вычислительных системах», пер. с англ., М.: Мир,1978 г.
2. Шумаков П., Фаронов В., «Delphi 4. Руководство разработчика баз данных», М.: Нолидж,1999
3. Уинкуп С. «Microsoft SQL Server 6.5 в подлиннике», пер. с англ., СПб.: BHV-Санкт-Петербург, 1998 г.
4. Грей П. «Логика, алгебра и базы данных», пер. с англ., М.: Машиностроение, 1989 г.
5. Архипенков С. «Аналитические системы на базе Oracle Espress. OLAP

Проектирование,создание, сопровождение», М.: Диалог-МИФИ, 1999 г.

Software development technological cycle

1. Iterative (spiral) software development model. Release concept.
2. Analysis and software design. CASE - tools and their use for automating the design of complex systems.
3. Management and planning. The concept of risk management. Project control using milestones (checkpoints or function points).
4. Version control systems - purpose and capabilities.
5. Progress in industrial testing (quality control) and error reporting.
6. Automation of program assembly. Make utility.
7. The concept of terms of reference.
8. Principles of testing. Classification of defects. Test-driven development.
9. Version control systems: cvs, svn, mercurial, git.
10. Quality management systems.
11. Structural design methods. Types of methods: top-down, bottom-up, iterative. Modularity. Principles of dividing the system into modules. Quality metrics of the modular structure. Gradual Refinement Method, Structural Diagrams (STD). Data Flow Diagrams (DFD). Jackson's Structured Programming Method (JSP).

Reference

1. Буч. Г. «Объектно-ориентированный анализ и проектирование с примерами приложений на C++», 2-е издание, пер. с англ., М.: Издательство Бином, СПб.: Невский диалект, 1999 г.
2. Липаев В. «Системное проектирование сложных программных средств дляинформационных систем», М.: СИНТЕГ, 1999 г.

Information security

1. Non-repudiation concept. Model of the system for ensuring non-repudiation. Information required to ensure non-repudiation.
2. Information security architecture. The consequences of the implementation of information security threats. Sources of information security threats.
3. Goals, objectives, methods and means of ensuring information security. Availability. Confidentiality. Identifiability.
Integrity. Warranty.
4. The concept of integrity. Integrity model. Basic ways to ensure integrity. Information needed to maintain integrity.
5. Formal models. Basic technical models for ensuring the information systems security. Security policy and forms of its presentation. Attribute model.
6. Criteria and classes of security of computer equipment and automated information systems.
7. Identification and authentication in programs. Storage of password images. Attacks on password authentication systems. Protection methods.
8. The concept of a computer virus. Life cycle of computer viruses. Types of computer viruses: file, boot, macro viruses.
9. Detection of software bookmarks. Unmasking signs of software bookmarks. Prevention of software bookmarks: firewalls, intrusion detection tools, antivirus tools, integrity control systems.
10. Masquerade attacks and their types. Ways to parry masquerade attacks.

11. Concepts of security audit and danger alert. Model of the security audit system. Signals and danger warning system. Intrusion detection systems.

Cryptography.

1. Cryptography and cryptanalysis. Cryptographic protocols and basic requirements for them. Encryption keys. Assumptions in cryptanalysis. Cryptographic strength of the information security system.
2. Substitution ciphers. Polyalphabetic substitution. Permutation ciphers.
3. Steganography. Methodology for the development and creation of an automated system in a secure design.
4. Protection of information by scaling. Methods for obtaining random and pseudo-random sequences.
5. Generators of pseudo-random sequences based on linear and non-linear shift registers.
6. Problems of distribution of keys. One-way functions.
7. Cryptosystem RSA and its mathematical justification.
8. Diffie-Hellman cryptosystem.
9. Canonical decomposition of natural numbers.
10. Modulo comparison. Fermat's little theorem. Euler function. Chinese remainder theorem.
11. Quadratic residues and non-residues, Gauss quadratic reciprocity law.
12. Secret sharing protocols.
13. Zero knowledge. protocols.
14. The concept and purpose of providing crypto keys. Crypto key provisioning model. The concept of the crypto key life cycle. Key distribution models. Protection of crypto keys. Certification. Certification center and its main functions.
15. The concept of confidentiality. Basic ways to ensure confidentiality. Functions of closing and disclosure of information. Information required for privacy.

Algebra of logic

1. Boolean variables.
2. Basic operations of the algebra of logic (negation, conjunction, disjunction, exclusive or).
3. Truth table.
4. Completeness of the system of functions.

Reference

1. Журавлёв Ю. И., Флёров Ю. А., Федько О.С. Дискретный анализ. Комбинаторика. Алгебра логики. Теория графов. М.: МФТИ, 2012

Theory of formal languages.

1. The concept of language.
2. Formal grammar.
3. Context-free grammar.
4. Context-sensitive grammar.
5. Finite-state automata.
6. Vending machines.
7. Suffix array.
8. Suffix automaton.

Reference

1. Ахо А., Ульман Дж. «Теория синтаксического анализа, перевода и компиляции», пер. сангл., М.: Мир, 1978 г.

2. Пратт Т. «Языки программирования», пер. с англ., М.: Мир, 1979 г.
3. Серебряков В. А., Галочкин М. П., Гончар Д. Р., Фуругян М. Г. «Теория и реализацияязыков программирования», М.: МЗ Пресс, 2006.

Classification of programming languages.

1. Procedural languages.
2. Logical languages.
3. Functional languages.
4. Markup languages (XML, TeX).

Reference

1. Хабибулин И. Ш. «Самоучитель XML» СПБ, БХВ-Петербург, 2003.

Computational geometry

1.The concept of a point and a vector. Appropriate data structures.
2.Dot product of vectors.
3.Vector product.
4.Oriented area of a triangle. The area of an arbitrary simple polygon.
5.Clockwise predicate. Intersection test of segments without calculating the intersection point.
6.Distances from a point to a line, from a point to a segment.
7.Finding the point of intersection of two lines. Normal equation of a straight line.
8.Intersection of a circle and a straight line. The intersection of two circles.
9.Convex hull (with complexity O(N log N))
10.Scan line method.

Parallel programming

1.Varieties of parallel architectures. SISD - MIMD
2.Varieties of parallel architectures. Common and shared memory.
3.MPI - definition and basic principles, groups and communicators (MPI_COMM_WORLD, MPI_Comm_rank(),...)
4.MPI_Init() and MPI_Finalize()
5.MPI_Send() and MPI_Recv()
6.Blocking and non-blocking passing, MPI_Isend() and MPI_Irecv()
7.Blocking and non-blocking receive, MPI_Sendrecv() and MPI_Rsend()
8.MPI_Bcast()
9.MPI_Reduce()
10.MPI_Scatter() and MPI_Gather(), MPI_Barrier()
11.Sorting and their parallelization, all2all and all2one.
12.Schemes of interaction of processes in sorting
13.Scheme of interaction of the hypercube type and its advantages.
14.Parallelization of array aggregation, fixed-sampling integration.
15.Amdahl's law (application and limitations)
16.Gustafson-Barsis law (application and limitations)
17.Batcher sorting. Resource allocation scheme.
18.Data decomposition, MPI_Status_ignore
19.Topologies, MPI_Cart_create() and MPI_Cart_coords()
20.Topologies, MPI_Cart_sub(), MPI_Cart_rank()
21.Topologies, MPI_Cart_Cart_get(), MPI_Cartdim_get()

22.MPI_Cart_shift() and vector operations
23.Decompositions of nonuniform grids
24.Wait functions: MPI_Wait(), MPI_Test(), using MPI_Status()
25.Graphics accelerators.
26.CUDA Technology
27.OpenCL language.
28.Programmable logic integrated circuits (FPGA).

Reference

1. Андреев С.С., Дбар С.А., Лацис А. О., Плоткина Е. А. Некоторые проблемы реализации вычислений на FPGA- ускорителях // Научный сервис в сети Интернет: труды XVIII Всероссийской научной конференции (19-24 сентября 2016 г., г. Новороссийск). — М.:ИПМ им. М. В. Келдыша, 2016. — С. 9-13. — URL:http://keldysh.ru/abrau/2016/32.pdf