ENTRANCE EXAMINATION PROGRAM
FOR PHYSTECH SCHOOL OF RADIO ENGINEERING AND COMPUTER TECHNOLOGY
INFORMATION TECHNOLOGIES AND TELECOMMUNICATIONS
COMPETITIVE GROUP
FOR APPLICANTS ENTERING PHD PROGRAMS

The exam ticket includes 2 questions. The first question is from the section of the program corresponding to the scientific specialty in which the applicant intends to study. The second question is about the applicant's future dissertation work: subject, existing groundwork, presence of a supervisor, publications. Questions can also be asked about the content of the final qualifying work (master's or specialist's).

1 hour is given for preparation and it is allowed to use books, with the exception of electronic media. It is not allowed to use different means of communication or the Internet. The applicant answers the exam ticket in the form of an oral interview, during which additional questions on the relevant section of the program may be asked.

Section 1. Computer systems and their elements

1. The first MP, CISC, RISC and Post-RISC architectures. The structure of microprocessors of various architectural platforms. Characteristics of microprocessors.
2. Organization of the pipeline in CISC - microprocessors, simple RISC - microprocessors, superscalar and VLIW - microprocessors.
3. The main groups of commands in the microprocessor command systems. Addressing modes. Command format and size.
4. Pipeline fetching commands. Command cache, trace cache, command pre-paging.
5. Transition processing. Transition prediction.
6. Grouping of instructions in superscalar microprocessors. Renaming registers in superscalar microprocessors.
7. Control elements in conveyor structures with dynamic command flow planning (scoreboarding, reservation station, reorder buffer).
8. Delayed writing and bypass in RISC microprocessor.
9. Memory hierarchy data cache of the first, second (third) levels.
10. Support for working with virtual memory.
11. Mechanisms for maintaining coherence in the memory hierarchy.
12. Organization of the main memory.
13. The structure of the microprocessor external interface. Tires. Rings. Switches. Networks.
14. Desktop PC and network PC. Workstations. Servers. cluster systems.
15. MRR. SMP. NUMA.
16. Basic settings of OSI/ISO standards. IEEE 802 series standards: LLC, MAC, and PHY sublayers.
17. Procedures for detecting and correcting corrupted bits in the frame structure. Basic media access procedures in MCSA/CD technology: channel capture, conflict detection, conflict resolution.
18. Sliding window flow control: group and individual acknowledgment.
19. Features of building high-performance fault-tolerant servers.

20. Advantages and problems of multiprocessor systems.
21. Architecture of symmetrical multiprocessor systems. Bus and switch structures.

22. Cluster and array-parallel systems. Topology, information transfer protocols and methods for maintaining data coherence.
23. Computing systems that combine memory with a microprocessor on a single chip.
24. Peripheral devices, their main characteristics.
25. Arithmetic devices. Fast pipeline algorithms.
26. Synchronization of parallel processes. General data and critical sections. Software and hardware methods of synchronization of parallel processes. Semaphores and queues.

Section 2. Mathematical and software support for computing systems, complexes and computer networks

1. Systems and programming languages, their classification according to different criteria. Methods for implementing languages in computers (compilers, interpreters, interpreter-type compilers). The concept of syntax and semantics. Formal definition of vocabulary, grammar and language.
2. Scalar types of languages like the C type. Simple variables, arrays, enumerated type. Pointers. Displaying them on different architectures of computers.
3. Structure of the C language as an example of a user-defined type. Type and object. Different ways to get objects. Structure pointers. Working with fields.
4. Procedural mechanism in algorithmic languages. Implementation methods for languages like C and Fortran languages. Methods for passing actual parameters. Procedure pointers.
5. Classes in C++ and Java languages. Hidden and interface parts of the type. Obtaining instances of classes (objects). Constructors and destructors. The use of classes in programming complex systems as a further development of modular programming.
6. Inheritance of classes. Rules for the formation of a new type. Constructors of inherited and derived types, their interaction. Rules for casting types along the chain of inheritance. Virtual functions. Multiple inheritance.
7. Redefining operations in the C++ Language as a means of increasing the abstractness and universality of programs. Examples of redefining binary, unary, pre- and post-fix operations. Polymorphism. Priorities when processing control characters such as "()".
8. Situational mechanism as a means of interaction between calling and called procedures. Giving and catching exceptions in C++ and Java. Try block. Implementation of the exception mechanism in stack.
9. Basic concepts of the Java system. Input language, its differences from C++. The concept of secure programming. Platform independence. General characteristics of the environment.
10. Parallelization of programs for modern computers. Models and types of parallelism. Support for parallelism in computer architectures. Levels of parallelism: pipeline, multiprocessor, multiprocessor.
11. Global (inter- and intra-procedural) analysis and optimization. Analysis of control flows and data. Classical direct and inverse algorithms of analysis and optimization (propagation of constants, live-variable calculations).
12. Flow control analysis. Structured and unstructured programs. Isolation of structured components. Interval analysis. Bringing control structures to the basic ones. Building a flow graph for a structured program.
13. Graph marking. The concept of the critical path. Retraction into the alternative optimization ". Elimination of false information dependencies. Optimization by dosed addition of control operations. Use of algebraic properties of operations.

14. Methods for optimizing cycles. Removal of invariants. Induction variables. Parallelism of cycles in a data flow machine and a multiprocessor system. Overlay or combination of operations. Read-ahead, write-back, register basing, loop exits
15. Analysis of dependencies in cycles. Index analysis as an integer programming problem. Solution of systems of linear Diophantine equations. Economical methods for solving integer inequalities. Fourier-Motzkin method. Identification of directions and distances of information dependencies.
16. Optimal command flow planning. Code compaction algorithms (priority scheduling of lists with optimal assignment of execution units for acyclic programs and pipelined loops).
17. Strategy of distribution of hardware resources when compacting the code. Optimization of registers based on the graph coloring algorithm.
18. The concept of the architecture of computing systems. Hardware and software components of the architecture. Various types of architectures and their examples.
19. The main components of modern operating systems and their characteristics.
20. Memory management in modern operating systems. The problem of mapping the address space. Segment, page and segment-page organization. Memory fragmentation (internal, external). Scavengers.
21. Process and task management. The concept of a process. Classification. Synchronization methods (semaphores, monitors). Java streams as an example of the implementation of monitors in a programming language.
22. File management. The structure of file systems, resource allocation and protection strategies, information management.
23. OC UNIX as a good example of a mobile operating system. General philosophy and main technical solutions (files, memory, processes, command language).

Section 3. System analysis, management and processing of information, statistics

1. Topological linear spaces. Metric spaces. Normed spaces. Examples.
2. Convex sets. Convex functions. Minkowski functional.
3. Linear functionals. Theorems on the extension of a linear functional.
4. Mathematical methods for modeling complex systems. Classification of methods for modeling complex systems. The main stages of system modeling. Methods and means of simulation of complex systems.
5. Concepts about the system approach, system analysis. Selection of the system from the environment, the definition of the system. System concepts: input, output, feedback, restrictions.
6. Methods of identification. Formulation of the problem and classification of identification methods. Estimation theory. Theory of statistical decisions. Bayesian approach. Minimax principle. Maximum likelihood method.
7. The problem of making a decision under uncertainty. Types of uncertainty and methods for its elimination.
8. Problems of multi-objective optimization and methods for their solution. Linear convolution of criteria. Benchmark method. The method of selecting the main criterion. Method for introducing a metric in the space of objective functions. Method of successive concessions. Pareto compromises. Pareto sets.
9. Preferences and utility functions.
10. Games in expanded and normal form. Nash equilibrium in pure and mixed strategies. Conditions for the existence of Nash equilibrium.

11. Basic concepts of control theory: goals and principles of control, dynamic systems. Dynamic system as a mathematical model of the control system.
12. Mathematical description of control objects: state space, transfer functions, block diagrams. Classification of control systems.
13. Concepts of controllability and observability of control systems.
14. Transfer function of a linear link. Weight function, transition function. Frequency characteristics of typical links.
15. The concept of stability. Stability of linear stationary systems. Mikhailov's criterion. Nyquist stability criterion.
16. Wiener-Hopf filtering. Optimal Kalman-Bucy filters.
17. Problem for a conditional extremum. The Kuhn-Tucker theorem and its applications.
18. The problem of linear programming. Simplex method. Ellipsoid method.
19. Complexity of algorithms. Turing machine. P and NP classes. NP complete and NP hard problems.
20. Branch and bound method
21. Statement of the problem of optimal control. Pontryagin's maximum principle and its connection with the calculus of variations.
22. Dynamic programming, Bellman equation. A sufficient optimality condition for an optimal control problem.
23. Basic concepts of queuing theory: incoming flows of requirements, queues, devices, service disciplines. Kendall’s notation.
24. Distribution of waiting time for the start of service in the queuing theory. Little’s formulas.
25. Markov processes. System of differential equations for state probabilities. Sufficient conditions for the existence of a stationary regime. A system of algebraic equations for determining stationary probabilities.
26. Methods for calculating the critical path in calendar-network planning. The tasks of determining the duration of the project. The main stages of the PERT method (Program Evaluation and Review Technique).
27. List scheduling for the task of scheduling and network planning in conditions of limited resources.
28. The concept of information and information entropy. Discrete communication channel and its capacity. Nyquist-Shannon theorem.
29. Laplace and Laplace-Stieltjes transforms, generating functions. Probability interpretation of the Laplace-Stieltjes transformation and the generating function.
30. Fourier transform, generalized functions.
31. Estimates, statistical solutions, hypothesis testing. Estimates of the parameters of statistical objects, linear regression. Least square method. LASSO algorithm, ridge regression.
32. Learning without a teacher. Problems and algorithms of clustering. k-means algorithm. Hierarchical clustering. EM algorithm.
33. Classification methods. Naive Bayesian classifier, nearest neighbors, support vector machines, decision trees.
34. Artificial neural networks. Principles and algorithms for learning ANN. Backpropagation algorithm.

Section 4. Management in organizational systems

1. The subject of control theory. Management relations and the concept of organizational management. Efficiency criteria and limitations in achieving the goal. The concept of feedback and its role in management. Formalization and formulation of control problems. Problems of analysis and synthesis of mechanisms of functioning and management of

socio-economic systems. The main structures and methods of managing socio-economic systems: administrative and organizational, economic, socio-psychological, etc.

2. Basic concepts of the system approach: system, element, structure, environment. System properties: integrity and articulation, connectivity, structure, organization and self-organization, integrated qualities. Organization as a system.
3. The concept of management functions and their classification, general and specific functions, strategic planning in organizational management systems, tactical and operational planning, operational management, organization and information interaction, models and methods of decision making.
4. Principles and criteria for the formation of management structures in socio-economic systems. The main types of organizational structures (linear, functional, combined, matrix), their evolution and development. Features of the formation of program-target management structures at various levels of the hierarchy.
5. Operations research methods. Queuing theory. Inventory management.
6. Statement of problems of mathematical programming. Optimization approach to the problems of managing socio-economic systems. Admissible set and objective function. Classification of problems of mathematical programming. Linear programming problem. Theory of duality. Simplex method. Nonlinear problems of mathematical programming. Local and global extremum, optimality conditions, Kuhn-Tucker conditions. Conditional extremum problems and the Lagrange multiplier method. The problem of stochastic programming. Discrete programming problem. The branch and bound method.
7. Fundamentals of graph theory: definition of a graph, chains, cycles, paths, contours. Shortest paths and contours. Maximum flow. Transport task. Assignment problem. Problems of resource allocation on networks and graphs. Dynamic programming method for multi-step decision making problems. Bellman's principle of optimality.
8. Subject and basic concepts of game theory. Application of game theory to optimize managerial decisions. Concept of strategy and game solution. Equilibria: in dominant strategies, maximin, Nash, Bayes, Stackelberg. Matrix games. Games with consistent interests. cooperative games.
9. Methods of multi-criteria evaluation of alternatives. Lots of compromise and agreement.
10. Decision making under conditions of uncertainty. Types of uncertainty. Statistical models of decision making. Bayes-Laplace criteria, Germeier criteria, Bernoulli-Laplace criteria, maximin criteria (Wald), Savage minimax risk criteria, Hurwitz criteria, etc.
11. Making collective decisions. Arrow's theorem and its analysis. Majority rules, Condorcet, Borda. Condorcet paradox. Modern concepts of group choice.
12. Models and methods of decision making with fuzzy information. Fuzzy sets. Basic definitions and operations on fuzzy sets. Fuzzy relations, operations on relations, properties of relations. Decision making with a fuzzy preference relation on a set of alternatives.
13. Socio-economic forecasting. Time series and their analysis.
14. Fundamentals of the theory of active systems. Scheduling mechanisms in active systems. Incentive mechanisms in deterministic active systems and active systems with uncertainty. Basic mechanisms for resource allocation, active expertise, competitive, multi-channel, cost-effective.
15. Goals, objectives and stages of project management. Methods of network planning and management. Project management mechanisms.
16. Tasks and methods of financial analysis. Mathematical foundations of financial analysis under risk and uncertainty. The problem of the optimal portfolio of securities.

Section 5. Methods and systems of information protection, information security

1. Architecture of information security. Consequences of the implementation of threats to information security. Sources of threats to information security.
2. Goals, objectives, methods and means of ensuring information security. Availability. Confidentiality. Identifiability. Integrity. Warranty.
3. The concept of integrity. Integrity model. Basic ways to ensure integrity. Information needed to maintain integrity.
4. Formal models. Basic technical models for ensuring the security of information systems. Security policy and forms of its presentation. Attribute model.
5. Criteria and classes of security of computer equipment and automated information systems.
6. The concept of access. Access control model (ACM). The main functions of the ACM system. ACM schemes (access lists, mandate scheme, access labels, context-sensitive scheme). Information required for ACM.
7. Cryptography and cryptanalysis. Encryption keys. Assumptions in cryptanalysis. Cryptographic strength of the information security system.
8. Problems of distribution of keys. One-way functions.
9. RSA cryptosystem.
10. Diffie-Hellman cryptosystem.
11. Canonical decomposition of natural numbers. Euclid's algorithms. Sieve of Eratosthenes.
12. Modulo comparisons. Fermat's little theorem. Euler function. Chinese remainder theorem.
13. The complexity of the algorithms for addition, multiplication, raising to an integer power.
14. Cryptographic protocols and basic requirements for them. Secret sharing protocols. Zero-knowledge proofs.
15. The concept of identification and authentication. Methods and schemes of authentication. Information required for authentication. Problems of security of authentication methods.
16. Classification of security threats. Typical architecture of the OS protection subsystem. Access control: basic concepts.
17. Static method for studying programs. Recovery of algorithms and data structures.
18. Dynamic method of studying programs. Basic principles of the debugger. Beacon method and tracing method. Features of parallel code analysis. Search and definition of encryption algorithms.
19. Protection against disassembly and debugging. Embedding security features in software.
20. Identification and authentication in programs. Storage of password images. Attacks on password authentication systems. Protection methods.
21. Basic methods of technical protection against unauthorized copying of programs and data. Identification of computer parameters. Electronic keys.
22. The concept of a computer virus. Life cycle of computer viruses. Types of computer viruses: file, boot, macro viruses.
23. Detection of software bookmarks. Unmasking signs of software bookmarks. Prevention of software bookmarks: firewalls, intrusion detection tools, antivirus tools, integrity monitoring systems.
24. Classification of security threats to the operating system.
25. Definition, structure and functioning of firewalls. What can and can't firewalls protect against. The concept of DMZ.

26. Structure, topology and architecture of computer networks. Reference model of interaction of open systems. Internet architecture. LAN architecture. Routing and flow control in computer networks.
27. Protocols of the transport layer and application layer of the Internet architecture.
28. Static and dynamic routing. Examples of dynamic routing protocols. Autonomous system. Default routes.

29. Unauthorized data exchange. Ways to bypass firewalls. Attacks. The point of failure of the entire system. Social engineering.
30. 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. Certifying center and its main functions.
31. The concept of database security. Database security threats: general and specific. Interpretation of security aspects for the database: confidentiality, integrity, availability.
32. Database access control. Basic concepts: subjects and objects, user groups, privileges, roles and views. Types of privileges: system and object. Use of user roles and privileges.
33. Using transactions and locks to ensure the integrity of data in the database. Committing and rolling back a transaction. Types of locks.
34. Masquerade attacks and their types. Ways to parry masquerade attacks.
35. Concepts of security audit and danger alert. Model of the security audit system. Signals and danger warning system. Intrusion detection systems.

Section 6. Automation and control of technological processes and production

1. Classification of control systems. Automatic and automated control systems (ACS) for technological processes (TP) and production.
2. Basic approaches to the analysis and synthesis of automatic and automated control systems.
3. Structures of control systems: open systems, systems with feedback, combined systems. Dynamic and static characteristics of control systems: transient and weight functions and their relationship, frequency characteristics. Typical dynamic links and their characteristics.
4. Quality of control processes in linear dynamic systems. Indicators of the quality of transient processes. Quality assessment methods. Correction of control systems.
5. Management under conditions of uncertainty. Positive dynamical systems: basic definitions and properties, stabilization of positive systems under uncertainty.
6. Classification of discrete automatic control systems. Stability of discrete systems. Study of stability in the first approximation, Lyapunov functions, comparison method. Elements of the theory of realization of dynamical systems.
7. Optimization approach to the problems of control of technological processes and production systems. Admissible set and objective function. Forms of recording problems of mathematical programming. Classification of problems of mathematical programming.
8. Optimization of the processes of planning by the management of the activities of industrial enterprises individually and at the multi-factory level.
9. Properties of complex systems. Basic principles of a systematic approach to assessing the state and managing complex systems. Weakly structured management tasks, methods and systems for making managerial decisions. Intelligent control systems.
10. The concept of data, data systems. Data objects. Object attributes. Data values. Data object identifiers. Object attributes. Data values. Data object identifiers, key data elements. The concept of data recording. Data files.

11. Databases. Database requirements. Distributed databases. Data models. Relational data model. Network data model. Hierarchical data model. Relationships between objects and attributes. Database management systems. Features of distributed database management and distributed database management system. Standards for data exchange between ACS subsystems.
12. Database design. Database life cycle. Conceptual model. Logical model. Data dictionaries, their purpose, integrated and independent data dictionaries.

13. Ordering of canonical structures. Synthesis of logical structures of local and distributed databases. Languages used in databases. Data description languages. Data manipulation languages. Abstraction levels for describing data.
14. Organization of ACS software. Technologies of structural and objective-oriented programming. Construction of abstract data types. Encapsulation of data and methods of their processing in object classes. Hierarchy of classes. Typical structures for describing abstract data (array, stack, queue, binary tree).
15. Programming of mathematical structures (matrices and finite graphs). Methods of program data processing. Iteration and recursion. Sorting and searching.
16. Programming technologies. Methodical and instrumental means of development of modular software ACS. Compiling and editing links. Verification and debugging of the program. Automation of development of software projects. Software documentation.
17. Methods of joint design of organizational and technological distributed complexes and control systems for them. Formalized methods of analysis, synthesis, research and optimization of modular structures of data collection and processing systems in automated process control system (APCS), automated enterprise control systems (AECS), automated systems for technological preparation of production (ASTPP).
18. Methods for effective organization and maintenance of specialized information and software for APCS, AECS, ASTPP including databases and data banks and methods for their optimization.
19. Methods for the synthesis of special software, application packages and standard modules, functional and supporting subsystems APCS, AECS.
20. Methods for planning and optimizing debugging, maintenance, modification and operation of the tasks of the functional and supporting subsystems of APCS, AECS, ASTPP, including the tasks of quality management, finance and personnel.
21. Methods of control, assurance, protection and redundancy of information and software APCS, AECS.
22. Theoretical foundations and applied methods for analyzing and improving the efficiency, reliability and survivability of automated control systems at the stages of their development, implementation and operation.
23. Theoretical foundations, methods and algorithms for diagnosing, (determining performance, troubleshooting and forecasting) APCS, AECS, ASTPP.
24. Theoretical foundations, methods and algorithms for intellectualization of the solution of applied problems in the construction of ACS for a wide range of purposes (APCS, AECS, ASTPP). Theoretical foundations, methods and algorithms for constructing expert and dialogue subsystems included in APCS, AECS, ASTPP.

References

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3. В. Шнитман. Современные высокопроизводительные компьютеры. М., Мир, 2003.
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Mathematical and software support for computing systems, complexes and computer networks

1. Б. Керниган, Д.Ритчи. Язык программирования Си. Санкт-Петербург, 2003.
2. Б. Страуструп. Язык программирования C++. 4-е издание, Addison-Wesley Professional, 2013.
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System analysis, management and processing of information, statistics

1. Антонов А.В. Системный анализ: учебник для вузов / А.В. Антонов. - М.: Высшая школа, 2004. -454 с.
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3. Поляк Б.Т., Хлебников М.В., Рапопорт Л.Б. Математическая теория автоматического управления. М.: ЛЕНАНД, 2019.
4. Теория управления (дополнительные главы): Учебное пособие / Под ред. Д.А. Новикова, М.: ЛЕНАНД, 2019.
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Methods and systems of information protection, information security

1. Компьютерные сети. 5-е издание. Э. Таненбаум, Д. Уэзеролл, М.: Мир, 2012.
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