**ENTRANCE EXAMINATION PROGRAM**
**FOR PHYSTECH SCHOOL OF RADIO ENGINEERING AND COMPUTER TECHNOLOGY**
**ELECTRONICS, PHOTONICS, ENGINEERING AND COMMUNICATION**
**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. Systems, networks and devices of telecommunications

1. Redundancy of the source of the message and the reasons for its appearance. Classification of methods for reducing redundancy, reducing statistical and semantic redundancy. C. Shannon's theorem on source coding. Constructive methods of source coding, coding of speech signals and video image signals.
2. The problem of ensuring high accuracy of transmission of discrete messages in channels with noise. Potential possibilities of discrete communication channels, C. Shannon's theorem for a discrete communication channel.
3. Potential possibilities of continuous communication channels in the transmission of discrete messages. Throughput of the communication channel.
4. The problem of error-correcting coding Classification of error-correcting codes.
5. Efficiency and energy gain of coding.
6. International standards for the compression of voice and video messages. Economical use of network resources when organizing video telephony and teleconferencing.
7. Basic concepts of queuing, classification of queuing systems (QS), typical distributions in the theory of queuing, performance indicators of QS. QS simulation methods.
8. Models of input streams. Stationary and non-stationary flows, Poisson flows, Erlang flows, Palm flows, Khinchin's theorem on the convergence of the sum of flows.
9. Markov queuing networks, modeling of data transmission systems by queuing networks.
10. Communication media. Wired and wireless communication lines.
11. ISO OSI, TCP IP models. Levels, protocols. Encapsulation and decapsulation.
12. Physical layer in the IEEE 802.11 standard. Physical layer protocols based on DSSS direct sequence spread spectrum and OFDM orthogonally separated frequency multiplexing.

13. ALOHA system. Modeling methods.
14. Carrier-sense multiple access (CSMA): persistent, non-persistent, p-persistent.

15. The principle of Ethernet operation. Ethernet frame attributes. MAC Ethernet. Multiple access method with carrier sense and collision detection CSMA/CD.
16. Channel access layer (MAC layer) in the IEEE 802.11 standard. CSMA/CA collision avoidance multiple access method with carrier sense and collision avoidance. DCF distributed control mode: basic method, RTS/CTS method. Fragmentation of data packets.
17. IEEE 802.11 network models with an ideal channel. Evaluation of performance indicators when using the basic access method and the RTS/CTS mechanism.
18. Methods for reliable multicast transmission in Wi-Fi and WiMAX networks. Their modeling and optimization.
19. Address resolution. Addressing in a corporate network. Using a hierarchical IP network addressing scheme. Description of IPv4 and IPv6. Structure of IPv4 and IPv6 addresses. Subnet mask. Unicast, broadcast and multicast IPv4. IPv4 and IPv6 address types.
20. Dynamic routing. Algorithms, protocols. Autonomous systems. Routing table. Determination of the optimal route. Prevention of switching loops.
21. Multihop Wi-Fi networks. IEEE 802.11s standard. Routing. The routing metric. Routing protocols: AODV, OLSR, HWMP.
22. The principle of operation of NAT. Static NAT. Dynamic NAT. NAT with overload. NAT setup.
23.Principles of operation of the TCP protocol. Overload prevention methods.
24. Point-to-point connections. HDLC encapsulation. How the PPP protocol works. Setting up the PPP protocol.
25. Cryptographic methods of information protection. Cryptographic models. Application examples in cryptography.
26. Authentication of user access to information resources. Electronic signature. Implementation. Digital certificate.
27. Methods and algorithms for encryption with public and private keys. Implementation.
28. Types of attacks on information. Attack detection systems.
29. Means of protection against attacks on information: firewalls, at the protocol level.

**Section 2. Radio engineering, television systems and devices**

1. Information, messages, signals, interference. The space of signals. Classification of radio signals. Mathematical models of radio engineering signals. The principle of dynamic representation of signals. Heaviside function and Dirac function.
2. Signal spectrum in a given system of basis functions. Signal approximation error by a finite series. Bessel's inequality.
3. Periodic signals and their representation in the basis of complex harmonic functions. Complex and trigonometric forms of the Fourier series. Discrete spectrum of a periodic signal.
4. Non-periodic signals. Spectral representation of non-periodic signals. Direct and inverse Fourier transforms.

5. Spectral signal density. Spectrum limited signals. Nyquist-Shannon theorem. Narrowband signals. Analytical signal. Complex envelope. Correlation analysis of signals. Autocorrelation function. Connection of the autocorrelation function with the spectrum of a deterministic signal.

6. Discrete representations of signals. Integral representations of signals. Fourier, Hilbert and other integral transformations.
7. Discrete signals and discrete transformations. Discrete Fourier and Hilbert transforms and their properties.
8. Discretization and restoration of signals. Fast algorithms for discrete transformations.
9. Elements of the theory of self-oscillators. Self-excitation modes, their features. Generators with external excitation. Frequency stability and methods for its increase. Stabilization using high-quality oscillatory systems (resonators). Quartz generators. Generators on dielectric resonators.
10. Power amplifiers. Summing up the power of generators.
11. Digital frequency synthesizers, direct and indirect synthesis, PLL.
12. Oscillation control (modulation). Fundamentals of the theory of linear and non-linear modulation.
13. Amplitude, phase, frequency modulations. Other (combined) types of modulation. Spectra of signals for various types of modulation. Block diagrams of modulators.
14. Signal frequency converters, mixers and heterodyne. Signal demodulators: amplitude, frequency and phase; block diagrams. Amplifiers of various frequency ranges.
15. Fundamentals of the theory of signal separation in multichannel radio systems for information transmission. Necessary and sufficient conditions for linear separation of signals. Frequency, time and phase separation of signals.
16. Physical principles used for the formation, transmission and reception of images. Generalized block diagram of a television system.
17. Television image, television signal, their structure and parameters. Form and frequency spectrum of the television signal.
18. Analog and digital television. TV signal standards.
19. High-definition television. Methods for recording a television signal. Basic standards.
20. Principles and methods of TV video signal compression. Standards, MPEG-2, MPEG-4.
21. Channel coding of TV video signals.
22. Multi-frequency OFDM modulation.
23. Features of terrestrial and satellite television.

**Section 3. Radar and radio navigation**

1. Signal spaces. Vector representation of signals. Orthogonal signals.
2. Spectral representations of signals. Fourier integral. Spectral amplitude density and energy spectrum.
3. Signal base. Uncertainty relation in signal theory. The signal with the minimum base. Complex impulse signals and their characteristics. Using complex signals to improve the resolution and accuracy of radar systems.
4. Radio signal uncertainty function and its properties. Response surface. Examples.
5. Stroboscopic processing of complex signals. Scheme of radio pulse strobing. Methods for generating a reference signal.
6. Basic equation of radar. Effective scattering surface, artificial targets.

7. Distance measurement methods: pulse, frequency and phase.
8. Methods for measuring angular coordinates: amplitude, phase, combined.
9. Doppler effect in radar. Target speed measurement.

10. Methods for reviewing space. Single-beam and multi-beam methods. Electronic scanning by antenna pattern.
11. Criteria for optimal detection. Criterion of minimum average risk.
12. Optimal detection of a fully known signal against the background of white Gaussian noise. Likelihood ratio. Matched filter.
13. Detection characteristics and threshold signals.
14. Signal detection with random parameters. Optimal detection of a signal with a random initial phase.
15. Optimum discrimination between two signals. Comparison of the potential accuracy of distinguishing AM, FM and PM signals in binary coding.
16. Conditional average risk, posterior probability density. Unbiased and efficient estimators. Optimal estimates of signal parameters.
17. Cramér-Rao border. The structure of the optimal parameter meter. Tracking meter. Comparison of noise immunity of AM, FM and FM signals.
18. Optimal estimation of the parameters of radio signals. Potential delay measurement accuracy. The structure of the optimal meter.
19. Potential frequency measurement accuracy. The structure of the optimal meter. PLL system.
20. Potential phase measurement accuracy. The structure of the optimal meter.
21. Potential accuracy of measurement of angular coordinates.
22. Representation of signals using orthogonal functions. Spectra of signals. Integral representations of signals. Fourier, Hilbert transforms. Radio signals, types of modulation. Frequency spectra of radio signals. Random processes and their representation. Discrete signals and discrete transformations. Discrete Fourier, Haar, Walsh-Hadamard, Z-transform. Discretization and restoration of continuous signals. Fast transformation algorithms, fast Fourier transform.

**Section 4. Antennas, microwave devices and their technologies**

1. Equations of the electromagnetic field. Material equations. Border conditions.
2. Radiation of electromagnetic waves. Vectorized Kirchhoff's formula.
3. Diffraction of electromagnetic waves. Diffraction at a rectangular hole.
4. Boundary problems of electrodynamics. Excitation of a flat layer with negative permittivity and permeability.
5. Waves in waveguides and coaxial lines. TE, TM and TEM waves - conditions of existence and features.
6. Methods for solving boundary problems of electrodynamics. Method of integral equations.
7. Microwave waveguide multipoles. Scattering matrix of a multipole. Basic properties of single-mode matrices.
8. Microwave line devices: branching, bridge connections, directional couplers - structure and main characteristics.
9. Control devices in microwave devices: attenuators, phase shifters, polarizers. Their structure, main characteristics.
10. Microwave devices using ferrites: phase shifters, valves, circulators. Structure and main characteristics.
11. Switching semiconductor microwave devices. Semiconductor phase shifters. Structure and main characteristics.
12. Microwave frequency filters. Classification, implementation options, main characteristics.

13. Software complexes for modeling microwave devices. CST Microwave Studio. Ansoft HFSS.
14. Features of active microwave devices based on semiconductor devices (generators, frequency multipliers, low-noise amplifiers). Applied modifications of transistors and diodes.
15. Features of high-power amplifiers and microwave generators based on klystrons, magnetrons, TWTs, gyroklystrons and gyrotrons.
16. Main characteristics of antennas. Directional characteristic. Gain.
17. Aperture antennas. Dependence of the main characteristics of radiation on the amplitude-phase distribution in the aperture. Statistical characteristics of antennas.
18. Horn antennas. Mirror antennas. Construction options, characteristics.
19. Vibrator and printed antennas. Construction options. Characteristics.
20. Phased arrays. Scanning methods. Lattice multiplier.
21. Broadband phased arrays. Requirements for controlled delay lines.
22. Phased arrays excitation circuits. Diagram formers of multibeam phased arrays.
23. Calibration and control of phased arrays.
24. Architecture of control systems of modern radio engineering systems. Basic digital interfaces.
25. Energy characteristics of transmitting and receiving active phased arrays. Requirements for channel amplifiers of active phased arrays.
26. Multichannel active phased arrays modules: structure and characteristics.
27. Digital and optical active phased arrays diagramming.
28. Measurement of parameters of antenna feeder devices.
29. Computer technologies for designing, calculating and optimizing antennas and microwave devices
30. Technology for the manufacture of antennas and microwave devices.

**References**

*Systems, networks and devices of telecommunications*


1. Компьютерные сети. Принципы, технологии, протоколы. / В.Г. Олифер, Н.А. Олифер. - СПб.: Издательство «Питер», 4-е издание 2010. -672 с.: ил.
2. Системы и сети передачи информации: Учебное пособие для вузов / Под ред. Р.Б. Мазепы. М.: Изд-во МАИ, 2001.
3. Гнеденко Б.В., Коваленко И.Н. Введение в теорию массового обслуживания. Изд. 4-е; испр. М.: ЛКИ, 2007.
4. Крухмалев В.В. Цифровые системы передачи: учебное пособие для вузов. – М.: Горячая линия-Телеком, 2012.
5. Вишневский В.М., Ляхов А.И., Портной С.Л., Шахнович И.Л. Широкополосные беспроводные сети передачи информации. – М.: Техносфера, 2005.
6. Фороузан Б.А. Криптография и безопасность сетей. БИНОМ. Лаборатория знаний, 2010. - 783 с.
7. Клейменов С.А. Информационная безопасность и защита информации. ИЦ"Академия", 2012. - 331 с.
8. Шаньгин В.Ф. Информационная безопасность компьютерных систем и сетей. ФОРУМ: ИНФРА-М, 2013.
9. Bianchi G. Performance Analysis of the IEEE 802.11 Distributed Coordination Function // IEEE Journal on Selected Areas in Communications. 2000. Vol. 18. pp. 535-548.
10. Ricardo C. Carrano, Luiz C. S. Magalhães, Débora C. Muchaluat Saade and Célio V. N. Albuquerque. IEEE 802.11s Multihop MAC: A Tutorial // IEEE Communications Surveys & Tutorials, V. 13, N. 1, 2011, pp.52-67.

11. Lyakhov A. Yakimov M. Analytical Study of QoS Oriented Multicast in Wireless Networks // EURASIP Journal on Wireless Communications and Networking. 2011. V.11. Article ID 307507.

*Radio engineering, television systems and devices*

1. Гоноровский И.С. Радиотехнические цепи и сигналы: Учебник для вузов. 5-е изд., перераб. и доп. – М.: Дрофа, 2006. ISBN: 5-7107-7985-7.
2. Баскаков С.И. Радиотехнические цепи и сигналы. — М: Высшая школа 2005.-462 с. ISBN: 5-06-003843-2
3. Тихонов В.И., Харисов В.Н. Статистический анализ и синтез радиотехнических устройств и систем. –М.:Связь. 2004. 608 с.
4. Шахтарин Б.И. Случайные процессы в радиотехнике: Учебное пособие. –М.: Радио и связь. 2000. 584 с.
5. Денисенко А.Н. Статистическая теория радиотехнических систем. – М.: АРИ, 2007. – 200 с.
6. Денисенко А.Н. Сигналы. Теоретическая радиотехника. Справочное пособие. – М.: Горячая Линия – Телеком, 2005. – 704 с.
7. Сергиенко А.Б. Цифровая обработка сигналов. – Санкт-Петербург.: «Питер», 2002 – 604 с.
8. Нефедов В.И., Сигов А.С. Основы радиоэлектроники и связи. - М.: Высшая школа, 2009. -735 с.
9. Зубарев Ю.Б., Кривошеев М.И., Красносельский И.Н. Цифровое телевизионное вещание. Основы, методы, системы. – М.: Научно-исследовательский институт радио (НИИР), 2001. – 568 с.
10. Мамчев Г.В. Теория и практика наземного цифрового телевизионного вещания. – М.: Горячая линия – Телеком, 2012. – 344 с.

*Radar and radio navigation*

1. Баскаков, С. И. Радиотехнические цепи и сигналы. М: Высшая школа, 2005
2. Радиотехнические системы. Казаринов Ю.М.(ред.): М.: Академия, 2008, 592 с.
3. Перов А.И. Статистическая теория радиотехнических систем. М: Радиотехника, 2003 г., - 400 с.
4. Бакулев П. А. Радиолокационные системы. М: «Радиотехника», 2007 г. – 376 стр.
5. Бакулев П.А., Сосновский А.А. Радионавигационные системы. М: «Радиотехника», 2005, 224 с.

*Antennas, microwave devices and their technologies*

1. Никольский В.В. Электродинамика и распространение радиоволн: учебное пособие для радиотехнических специальностей вузов/ В.В.Никольский, Т.И. Никольская. – 6-е изд. – М.: Эдиториал УРСС, 2012 . – 544 с.
2. Б. М. Петров, Электродинамика и распространение радиоволн. 2-е издание. М.: Горячая линия – телеком, 2007.

3. Ю. В. Пименов, В. И. Вольман, А. Д. Муравцов, Техническая электродинамика. М.: Радио и связь, 2002.
4. C. A. Balanis, Advanced engineering electromagnetics. N.Y.: John Wiley & Sons, 1989.
5. А. Ю. Гринев, Численные методы решения прикладных задач электродинамики. М.: Радиотехника, 2012.
6. Устройства СВЧ и антенны. Проектирование фазированных антенных решеток. – Учебное пособие для ВУЗов. Под ред. Д.И. Воскресенского, М.,»Радиотехника», 2012.
7. Сомов А.М., Кабетов Р.В. Антенно-фидерные устройства. – М.: Горячая линия - Телеком, 2011
8. Д.М. Сазонов, Антенны и устройства СВЧ. – М.: Высш. шк., 1988.
9. Balanis C.A. Antenna Theory, Analysis and Design. John Whiley & Sons, 2005
10. Mailloux R.J. Phased Array Antenna Handbook. Artech House, Inc. 2005
11. Гостюхин В.Л., Трусов В.Н., Гостюхин А.В. - Активные фазированные антенные решетки. М., «Радиотехника», 2011.
12. Проектирование СВЧ устройств и антенн с ANSOFT HFSS. С.Е.Банков, А.А.Курушин. Издательство Москва 2009, 736с.
13. Л.Г. Гассанов и др. Твердотельные устройства СВЧ в технике связи. "Радио и связь", М., 1988 г.
14. М.В.Вамберский, В.И.Казанцев, С.А.Шелухин. Передающие устройств СВЧ "Высшая школа", М., 1984 г.
15. Кравченко В.Ф. Цифровая обработка сигналов и изображений в радиофизических приложениях. Москва.: ФИЗМАТЛИТ, 2007