PROGRAM OF THE ADMISSION TEST FOR THE COMPETITION GROUP "PHYSTECH SCHOOL OF ELECTRONICS, PHOTONICS AND MOLECULAR PHYSICS - PHYSICAL SCIENCE" FOR APPLICANTS TO DOCTORAL PROGRAMS

At the admission test one will be asked questions on the graduate qualification paper and questions from the section corresponding to the area of the applicant's future research activities.

Questions on the graduate qualification paper (Master's or Specialist's degree programs)

1. Fundamental provisions.
2. Novelty.
3. Topicality.

Questions from the section corresponding to the area of the applicant's future research activities

1. Structure of a solid as one of the condensed states. Crystalline and amorphous solids. Translational symmetry. Lattice cell. Bravais lattice. Point and space groups. Peculiarities of wave propagation in periodic structures. Bragg's law. Reciprocal lattice. Brillouin zone.
2. Crystallographic defects. Point defects, their formation and diffusion. Vacant lattice site. Interstitial atom. Atomic defect complexes. EAdge and screw dislocations. Burgers vector. Energy of a dislocation. Crawling and sliding. Dislocation multiplication. Frank-Read source. The effect of radiation, mechanical and thermal effects on the real structure of solids.
3. Types of chemical bonds. Structural and physical features of ionic, covalent, metallic and molecular crystals. Closest packing.
4. Amorphous solids, metallic glasses, semiconductors, magnetics and their properties.
5. Description of energy state of a crystal using the quasi-particle gas. Examples of quasiparticles. Phonons, magnons, excitons, plasmons, etc. Electrons in metal as quasiparticles. Quasi-momentum. Dispersion law. Bloch's theorem. Boundary conditions. Density of states. Quasi-particle gas statistics. Bosons and fermions. Quasiparticles interaction.
6. Lattice-phonon vibrations. Acoustic and optical branches of vibrations. Lattice heat capacity. Debye frequency. Debye-Waller factor in x-ray scattering. Anharmonicity and thermal expansion.
7. Electronic states in crystals. One-electron model. Approximations of strong and weak ties. Band theory and physical properties of solids. Degenerate electron gas. Electronic specific heat, Fermi surface. Effective mass tensor. Electrons and holes. Cyclotron mass. Position of the Fermi level in nondegenerate semiconductors.
8. Kinetic equation. Electrical and thermal conductivity. Relaxation time. Electron scattering mechanisms. Scattering by impurities and defects. Electron phonon collisions. Normal processes, umklapp scattering. Magnetoresistance and Hall Effect.
9. Metals with long electron path lengths. Anomalous skin effect. Cyclotron resonance and size effects. Penetration of an electromagnetic field through metal. Helicons. Orbit quantization in a magnetic field. De Haas-Van Alphen effect.

10. Semiconductors. Electronic structure of typical semiconductors. Germanium. Narrow-gap semiconductors. Impurity levels. Donors and acceptors. Temperature dependence of conductivity. p–n junctions. Photoconductivity. Recombination and relaxation of nonequilibrium carriers. Hot carriers. Gunn effect.
11. Elastic constant tensor and elastic deformation. Crystal plasticity. Yield strength. Hardening. Internal friction.
12. Photon absorption mechanisms. Free carrier absorption. Lattice absorption. Multiphoton processes. Raman scattering of light in crystals. Absorption by bound carriers. Selection rules. Interband direct and oblique transitions. Excitons. Luminescence. Excitation lifetimes, fluorescence. Nonradiative transitions. Luminescence quantum yield.
13. Diamagnetism of free electron gas. Spin paramagnetism. Curie's law. Ferromagnetism. Weiss molecular field. Exchange interaction. Ferromagnetic domains. Anisotropy energy. Domain boundary. Antiferromagnetic materials. Ferrites. Spin-dependent phenomena. Internal magnetic fields, their components and effects on the state of nuclear levels.
14. Effective field. Electrostriction and piezoelectricity. Pyroelectrics and ferrielectrics. Electrical hysteresis.
15. Anomalies of ferroelectric physical properties in phase transitions. Molecular crystals.
16. Phase equilibrium. First-order and second-order phase transitions. Fluctuations. Solid solutions and intermediate phases.
17. Equilibrium in multicomponent systems and phase rule. Equilibrium diagrams. Diffusion and diffusionless transformations. Phase transformation kinetics.
18. Basic properties of superconductors. Meissner effect. Type-I and type-II superconductors. Vortices and vortex structures.
19. Fundamentals of microscopic and thermodynamic theories. Cooper pairs. Energy gap and quasiparticles in a superconductor. Quantum tunnelling. Josephson effect.
20. High-temperature superconductors, their structure, chemical composition. The role of oxygen in HTSC (high-temperature superconductors).
21. Radiography: methods for studying ideal and real structures. Electronography and electron microscopy. Neutronography: elastic and inelastic coherent scattering, investigation of magnetic structures and phonon spectra. Mössbauer effect, EPR, NMR.
22. Electrical and galvanomagnetic measurements as methods for studying the electronic structure of crystals and composition of impurities in semiconductors.
23. Optical research methods. Laser light sources opportunities.
24. Conditions for irradiation of materials in modern nuclear power plants. Elastic and inelastic collisions of bombarding particles with atoms of matter. Ionization processes in crystals. Primary knocked-on atoms, their spectra. Channeling.
25. Formation of defects under irradiation. Formation of Frenkel pairs in irradiated crystals. Atom-atom collision cascades. Radiation damage annealing.
26. Changes in the structure and properties of irradiated metals. Diffusion processes under irradiation: radiation-accelerated and radiation-induced phase-structural transformations in irradiated alloys. Swelling and irradiation creep.
27. Ion implantation in metals.

28. Methods for studying near-surface layers of a solid body. Low-energy electron diffraction, electron Auger spectroscopy, photoelectron spectroscopy, mass spectroscopy of secondary ions.
29. Electron transmission and scanning microscopy of defects in metals.
30. Application of EPR and NMR methods in radiation physics of solids.
31. Influence of imperfections in the structure of solids on the Mössbauer spectra parameters.

Literature

To the section "Condensed Matter Physics"

1. Kittel Ch. Introduction to Solid State Physics. M., Nauka, 1978.
2. Ashcroft N., Mermin N. Solid State Physics, vols. I and II. M., Mir, 1979.
3. Wert Ch., Thomson R. Solid State Physics. M., Mir, 1969.
4. Ziman J. Principles of the Rigid Bodies Theory. M: Mir, 1974.
5. Pavlov P.V., Khokhlov A.F. Solid State Physics. M.: Vysshaya Shkola, 2000.
6. Vonsovsky S.V. Magnetism. M., Nauka, 1971
7. Bonch-Bruevich V.L., Kalashnikov S.G. Physics of semiconductors. M:, Nauka, 1979.
8. V.V. Schmidt "Introduction to the Superconductivity Physics". MCCME, Moscow, 2000.