Entrance exam program in training of
Highly qualified personnel
(Ph.D programme)
1.1 "MATHEMATICS AND MECHANICS"

Entrance exam program for the postgraduate Ph.D. programme in training of highly qualified personnel 1.1. "MATHEMATICS AND MECHANICS"; by scientific specialty: 1.1.10 Biomechanics and Bioengineering includes the following sections:

PHYSICS. Mechanics. Basic laws of mechanics. Space and time in physics. Methods for measuring length and duration (in laboratory practice, on a cosmic scale, in the microcosm). Material point. Inertial reference system. The phenomenon of inertia. Newton's first law. The movement of a material point under the action of a force. Mass as a measure of inertia. Newton's second law. Interaction of material points. Newton's third law. gravitational field. Mass as a source of the gravitational field. The law of universal gravitation. Equality of gravitational and inertial masses. Molecular physics. Thermodynamics and statistical physics.Basic concepts and postulates of thermodynamics. macroscopic system. Fundamentals of the molecular-kinetic theory of the structure of matter. Thermodynamic and statistical methods of description. External and internal parameters. Thermodynamic state and its functions. The state of thermodynamic equilibrium. Postulates of thermodynamics. Establishment of thermodynamic equilibrium in an isolated system. Equilibrium and non-equilibrium processes. Thermodynamics. Internal energy, heat and work. First law of thermodynamics. Heat capacities and latent heats. Isoprocesses and gas laws on the example of ideal gas and van der Waals gas. Cyclic processes, thermal and refrigerating machines. The second law of thermodynamics. Entropy. The second law of thermodynamics for non-equilibrium processes. Clausius inequality. Third law of thermodynamics (thermal Nernst theorem). Behavior of thermodynamic quantities at a temperature tending to absolute zero. Thermodynamic potentials, equilibrium conditions and phase transitions. Internal energy, free energy, Gibbs potential, enthalpy. Thermodynamic potentials for systems with variable mass. chemical potential. Basic relation of equilibrium thermodynamics. Conditions of thermodynamic equilibrium. Homogeneous and heterogeneous systems. General conditions of thermodynamic equilibrium. Necessary conditions for the equilibrium of a two-phase one-component system. Conditions for the stability of the equilibrium of a single-phase system. Le Chatelier's principle. Phase transitions of the first kind. Behavior of thermodynamic quantities during phase transitions of the first order. Equation of Clapeyron - Clausius. Melting. Sublimation. Evaporation and boiling, saturated vapor pressure. Edge angle. Wetting. capillary phenomena. metastable states. Triple point. Critical point. Gibbs phase rule. Phase transitions of the second kind. Behavior of physical quantities during phase transitions of the second kind. Fareus-Lindqvist effects. Fundamentals of statistical physics. phase space. Gibbs ensemble (statistical ensemble). distribution function. Liouville's theorem. Microcanonical distribution. Canonical Gibbs distribution. Relationship between the partition function and free energy. Maxwell-Boltzmann distribution. The theorem on the equipartition of kinetic energy over degrees of freedom. Heat capacity of a classical ideal gas. non-ideal gases. Van der Waals gas. Gibbs grand canonical distribution. quantum statistics. Fermi-Dirac and Bose-Einstein distributions. General properties of Fermi gases. Fluctuations. Fluctuation probability distribution (Gaussian distribution). Fluctuations in an ideal gas. Physical kinetics. Partial distribution functions. Kinetic Boltzmann equation. Diffusion. Fick's laws. Viscosity. Newton's law. Mechanisms of internal friction (viscosity) in gases, liquids, solids. Superfluidity. Thermal conductivity. Fourier's law. Mechanisms of heat conduction in gases, liquids, solids. Electrical conductivity. Drude-Lorentz

formula for electrical conductivity. Electricity and magnetism. Basic laws of physics of electromagnetic phenomena. Electric charge and its properties. The law of conservation of electric charge. Coulomb's law. Electric field. Electric field strength. Gauss theorem. Generalization of Coulomb's law in the form of a differential equation. Potentiality of the electric field of immobile charges. Potential of the field of a point charge. The potential of the system of charges. Electricity. The magnetic field of the current. Biot-Savart-Laplace law. bias current. The phenomenon of electromagnetic induction. Faraday's law of electromagnetic induction. Lenz's rule. Electrical circuits. Resistance. Ohm's law. Capacity. Capacitor. Capacitor in AC circuit. Capacitor resistance to alternating current (capacitance). Self- and mutual induction. Inductance in an alternating current circuit. inductive resistance. Electrical circuits. Kirchhoff's rules for direct and alternating currents. AC resistance. AC power. Alternating current and its application. Oscillatory circuit. Electromagnetic waves. Wave equation for electromagnetic field. Plane monochromatic electromagnetic waves and their main properties (frequency and wave number, frequency-wave number relationship (dispersion law), propagation velocity, field orientation). Energy density and energy flux density of the electromagnetic field. EMW radiation by a Hertzian dipole. spherical waves. Interaction of charges and currents with an electromagnetic field. Lorentz force. Movement of a charge in an electric field. Movement of a charge in a magnetic field. Accelerators of charged particles. The force acting on a current-carrying conductor in a magnetic field (Ampère force). Magnetic moment of closed current. Interaction of the magnetic moment with the field. Conversion of energy in the field of alternating currents. Electric motors and alternators. Material media in an electromagnetic field. Macroscopic electromagnetic fields in media. Maxwell's equations. Material equations. Dielectric and magnetic permeability. Dielectrics. Related charges. Polarization of dielectrics in an electric field. Polarization vector. Electrical susceptibility (polarizability). Polar and non-polar dielectrics. Features of their behavior in constant and variable fields. Magnetic properties of matter. Magnetization vector. molecular currents. Dia-, para- and ferromagnets. Magnetic permeability and magnetic susceptibility. The nature of diamagnetism. Landau diamagnetism. Spin magnetic moment. The nature of para- and ferromagnetism. Application of para- and ferromagnetism. Superconductivity. Electrical and magnetic properties of superconductors. High temperature superconductivity. Optics. Geometric optics and photometry. Laws of geometric optics. Centered optical system and its cardinal elements. Construction of images in converging and scattering thin lenses. Transverse magnification of optical instruments. Optical instruments: eye, magnifying glass, microscope, telescope. Geometric optics as the limit of wave optics. Basic photometric quantities: light flux, luminous intensity, brightness, luminosity, illumination, light intensity. Spectral sensitivity of the eye. Wave optics. electromagnetic nature of light. Transverse electromagnetic waves. Polarization, types of polarization of a light wave. Polarizers. Malus' law. Light interference, Double-beam and multi-beam interference. Coherence. Optical travel difference. Methods for obtaining and calculating the interference pattern. Classical interference experiments. Interferometers. Diffraction. Huygens-Fresnel principle. Fresnel diffraction. Fresnel diffraction by round holes and obstacles. Fresnel zones. Fraunhofer diffraction. Diffraction gratings. Calculation of the diffraction pattern of light on a grating. X-ray diffraction. Spectral instruments, main characteristics of spectral instruments. Holography: recording and restoration of the image. Emission of light. Classical physical model of light emission. The natural width of the spectral line. Spectral line shapes. Broadening of spectral lines. Kirchhoff's laws for thermal radiation. Spectral density of radiation. The concept of a completely black body and the laws of its radiation. Quantum physical model of light emission. Planck's formula for black body radiation. Spontaneous and stimulated emission of light by atoms. Propagation of light in various media. Reflection of light from the interface between two isotropic media: Fresnel theory, Brewster angle. total internal reflection. Light guides. dispersion of light. Electronic theory of light dispersion. Phase and group speeds of light. Booger's law. Scattering of

light, Rayleigh scattering of light. Propagation of light in anisotropic media. Optical axes. Birefringence and its application. Optically active media, Faraday effect in magnetic media. Nonlinear environments. Effects in the propagation of light in nonlinear media. Industrial robotics. Development of domestic robotics. Working bodies of manipulators. Basic principles of organizing the movement of robots. Description of manipulators. Classification of drives: pneumatic drives, hydraulic drives, electric drives, combined drives. Actuator sensors and communication devices with control objects.

BIOENGINEERING. Biological aspects of biotechnology**.** General biology, microbiology and cell physiology. Definition of life and properties of the living. Levels of organization of living matter. The cell as the basis of heredity and reproduction. The structure of the nucleus and its role in heredity. The chemical composition of the cell (nucleic acids, proteins, polysaccharides, lipids, nucleoproteins, glycoproteins, lipoproteins, peptidoglycans, polyphosphates, mineral components and water). The structure and functions of the cell (differences between prokaryotic and eukaryotic cells). The structure of the bacterial cell wall. Life cycle of cells and types of cell division (amitosis, mitosis, meiosis). Chemical aspects of biotechnology. Bioorganic chemistry and biochemistry. The main objects of research of bioorganic chemistry. Research metods: chemical, physical, physicochemical, biochemical. Squirrels. Amino acids as monomeric structural units of proteins and peptides. Protein structure levels. Primary structure: methods for determining the sequence of amino acids, sequencers. Secondary structure of proteins: alpha and beta structures. Tertiary and quaternary (subunit) structures of proteins. The role of hydrogen, ionic, disulfide bonds, hydrophobic interactions. Denaturation (reversible, irreversible) of proteins. Nucleic acids. DNA and RNA. Double helix of DNA. Base complementarity. Methods for determining the nucleotide sequence in nucleic acids. Restriction, restriction enzymes. Technological aspects of biotechnology. The main bio-objects of biotechnology: industrial microorganisms, cells and tissues of plants, animals and humans, biocatalysts, including reconstructed producers of biologically active substances (selection, recombinant DNA method, hybridoma technology)**.** Raw material for biosynthesis and assessment of its biological value. The main sources of carbon, nitrogen, phosphorus, trace elements. Research of new sources of raw materials (including the issues of its pre-treatment), development of new nutrient media, including those including biostimulants and other elements of control and optimization of biosynthesis processes. Methods for optimizing nutrient media. Medical biotechnology (biotechnology for medicine). The use of methods of immobilization of biological objects in medical biotechnologies and in the diagnosis of diseases. Types of vaccines and their design. Cultural and genetically engineered vaccines. Technologies for in vitro cultivation of plant cells and tissues for the production of phytopreparations and therapeutic and prophylactic additives. Scientific bases of engineering design of biotechnologies. Fundamentals of Bioreactor Modeling.

CONCEPTUAL MODELS OF INFORMATICS. General principles of environmental modeling. General principles for modeling the environment, human thinking processes and human-machine communication. Machine representation of knowledge and data. Methods of data storage, search and processing, methods of natural language human-machine communication. Cognitive (intelligent) systems. Declarative and procedural representation of the external world. Knowledge and competence, perception, thinking and motor excitation. Knowledge base and database. Representation of knowledge. Classification systems: hierarchical classifications, faceted classifications, alphabetic-subject classifications. Thesaurus methods of knowledge representation.

Recommended literature:

1. Ovchinnikov Yu.A. Bioorganic chemistry. M.: Enlightenment, 1987
2. Shchelkunov S.A. genetic engineering. Part 1. Novosibirsk: NGU, 1994
3. Biotechnology. (Textbook for universities, edited by Egorov N.S., Samuilov V.D.). In 8 books. Moscow: Higher School, 1987
4. Manakov M.N., Pobedimsky D.G. Theoretical foundations of microbiological production technology. Moscow: Agropromizdat, 1990, 272 p.
5. Varfolomeev S.D., Kalyuzhny S.V. Biotechnology: Kinetic foundations of microbiological processes. M.: Higher school, 1990, 296 p.
6. Elinov N.P. Fundamentals of biotechnology. St. Petersburg: Nauka (Siberian Branch), 1995, 600 p.
7. Gracheva I.M., Krivova A.Yu. Technology of enzyme preparations. M.: Elevar, 2000, 512 p.
8. Bailey J., Ollis D. Fundamentals of biochemical engineering. In 2 volumes. M.: Mir, 1989
9. Theoretical foundations of biotechnology. Biochemical bases for the synthesis of biologically active substances / Butova S.N., Tipiseeva I.A., El-Registan G.I. Ed. THEM. Gracheva // -M. : Elevar, 2003, 554 p. 12. Enzymatic processes in biotechnology A.M. Bezborodov, N.A. Zagustina, V.O. Popov, M.: Nauka, 2008.-335 p.