МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
Федеральное государственное автономное образовательное учреждение высшего образования
«Севастопольский государственный университет»

УТВЕРЖДАЮ

Председатель приемной комиссии

Ректор

_______________ В.Д. Нечаев
(подпись) (Ф.И.О)

«20» января 2026 г.

ПРОГРАММА ВСТУПИТЕЛЬНОГО ИСПЫТАНИЯ

Профессиональное вступительное испытание
(название вступительного испытания)

направление подготовки **03.04.02 Физика (на английском языке)**
(шифр и название направления подготовки)

уровень высшего образования **магистратура**
(название уровня ВО)

квалификация **магистр**
(название)

Севастополь
2026

Program of entrance professional testing for admission to study in the direction of training 03.04.02 Physics:

1. **Developed** at the department "Marine Sciences and Technologies" of the Federal State Autonomous Educational Institution of Higher Education "Sevastopol State University" in accordance with the following regulatory documents:

– The procedure for admission to study in educational programs of higher education - bachelor's programs, specialty programs, master's programs, approved by order of the Ministry of Education and Science of Russia dated November 27, 2024 No. 821;

– Rules for admission to the federal state autonomous institution of higher education "Sevastopol State University" for study in educational programs of higher education - bachelor's programs, specialty programs, master's programs in 2026;

– Regulations on the admissions committee of the federal state autonomous institution "Sevastopol State University";

– Regulations on the examination commissions of the federal state autonomous institution of higher education "Sevastopol State University";

– Federal state educational standard of higher education in the field of study 03.03.02 Physics (undergraduate level), approved by Order of the Ministry of Science and Higher Education of the Russian Federation of August 7, 2020 No. 891;

– The main educational program of higher education in the direction of training 03.04.02 Physics, adopted by the decision of the Academic Council on 02/27/2025, protocol No. 9, approved by the rector of the Federal State Autonomous Educational Institution of Higher Education "Sevastopol State University" on 03/04/2025.

2. **Program developers**: Zavyalova O.S., Ph.D., Associate Professor, Head of the Department of Physics; Kostyukov V.V., Ph.D., Associate Professor, Professor of the Department of Physics; Rybakova K.A., Ph.D., Associate Professor, Associate Professor of the Department of Physics; Voronin D.P., Ph.D., Associate Professor of the Department of Physics.

3. **Approved** at the meeting of the department of Physics on December 26, 2025, protocol No. 4.

Chairman of the professional examination committee, Professor of the Department of Physics	(signature)	23.12.2025 (date)	V.V. Kostyukov
Head of the Department of Physics	(signature)	23.12.2025 (date)	O.S. Zavyalova

CONTENT

1. GENERAL PROVISIONS AND PROCEDURE FOR CONDUCTING THE ENTRANCE TEST

The competitive entrance exam for the specialty is conducted by an examination committee, the personnel of which is approved by order of the rector of SevSU. The competitive entrance exam program is intended for applicants entering master's programs in the direction of 03.04.02 Physics. The purpose of the competitive entrance exam program for a specialty is to assist applicants in independent preparation for passing the exam, incl. in systematizing and consolidating the knowledge acquired during the learning process in the disciplines of the professional training cycle in the specialty. The program focuses students on generalizing knowledge about the main sections of the course in general and theoretical physics. The main purpose of the competitive entrance exam is to generate a competitive score, which, in addition to the exam grade, contains the average score of the bachelor's diploma. The form and content of the competitive entrance exam provide control over the fulfillment of the requirements for the level of training of applicants who have a bachelor's degree in the field of 03.03.02 Physics.

The applicant must have a systematic understanding of the physics course and basic terms and physical laws. He must be able to solve physical problems and be able to explain basic laws and definitions. Lists of applicants admitted to the competitive entrance exam for their specialty are approved by the protocol of the admissions committee. The competitive entrance exam for the specialty includes tasks in the following disciplines of the professional training cycle in the direction 03.04.02 Physics:

- Mechanics;
- Molecular physics;
- Electricity and magnetism;
- Optics;
- Physics of the atom and atomic phenomena;
- Physics of the nucleus and elementary particles;
- Classical mechanics and fundamentals of continuum mechanics;
- Electrodynamics;
- Quantum theory;
- Thermodynamics and statistical physics.

The competitive entrance examination is conducted in written form. The task for the entrance exam is determined by the ticket, which includes the theoretical and practical parts of the task. The ticket includes eighteen theoretical questions on the subjects included in the competitive examination. The practical part of the assignment contains two tasks. Each student is given two astronomical hours to conduct the competitive entrance exam. All students take the exam at the same time. The results of the competitive entrance exam are determined using a one hundred (100) point system. The decision of the certification commission to evaluate the knowledge identified during the competitive entrance exam is made by the certification commission at a closed meeting. The marks are announced to the students after the completion of the competitive examination marksheet on the next day after the examination. If the applicant does not agree with the assessment given by the certification commission, he has the right to file an appeal in the manner prescribed by the Regulations on the SevSU Admissions Committee.

2. THE MAIN CONTENT OF THE ENTRANCE TEST PROGRAM

Section 2.1. MECHANICS

Elements of kinematics. The idea of the properties of space and time underlying classical mechanics. Physical models. Frames of reference. Kinematic description of movement.

Movement of a material point in a circle. Speed and acceleration during curved motion. Normal and tangential acceleration. Radius of curvature of the trajectory. Rotational motion of an absolutely rigid body and its characteristics.

Dynamics of a material point and translational motion of an absolutely rigid body. Inertial reference systems. Newton's laws. Interaction of bodies. Equation of motion. Momentum change theorem. The law of conservation of momentum and its connection with the homogeneity of space.

Mechanical work and kinetic energy, power. Conservative and non-conservative forces.

Energy as a universal measure of various forms of matter motion and interaction. A physical field as a form of matter that carries out force interaction between particles of matter. Potential energy of a material point in an external force field. Field of central forces. Potential energy of the system. The law of conservation of energy in mechanics and its connection with the uniformity of time. Energy dissipation.

Dynamics of rotational motion of an absolutely rigid body. Moment of force and angular momentum about a fixed point and a fixed axis. Basic equation for the dynamics of rotational motion. Moment of inertia. The law of conservation of angular momentum and its connection with the isotropy of space.

Kinetic energy of a rotating body. Huygens-Steiner theorem. Free axles. Gyroscope and its practical application.

Mechanical vibrations and waves. Harmonic vibrations. Differential equation of undamped oscillations. Mathematical, spring, physical pendulums. Energy of harmonic vibrations.

Damped oscillations. Logarithmic damping decrement. Good quality. Damped oscillations using the example of a spring pendulum. Forced oscillations. Amplitude and phase of forced oscillations. Resonance.

propagation in an elastic medium. Equation of traveling plane and spherical waves. Phase speed. Wave equation. Superposition principle. Wave packet. Group speed.

Interference and diffraction of waves. Formation of standing waves. The standing wave equation and its analysis. String vibrations. Doppler effect. Sound waves. Speed of sound waves in gases.

Gravity. Kepler's laws and consequences from them. The law of universal gravitation. The gravitational field and its characteristics. Potential energy of the gravitational field.

Conditions for elliptic, pairs of abolic and hyperbolic motion. Calculation of planetary orbital parameters. Accounting for the movement of the Sun. Application of the laws of universal gravitation to the problem of earthly gravity. Gravity and body weight. Weightlessness. Cosmic speeds.

Non-inertial reference systems. Inertia forces during accelerated translational motion. Centrifugal forces of inertia. The Coriolis force and its influence on the movement of bodies near the earth's surface. Foucault pendulum.

Gravitational mass and generalized Galileo's law. The principle of equivalence of gravitational forces and inertial forces.

Elements of special and partial theory of relativity. Galilean transformations and the mechanical principle of relativity. Consequences. Basic concepts of pre-relativistic physics, their limitations. Postulates of SRT. Lorentz - Fitzgerald transformations and conclusions from them.

Corollaries from Lorentz transformations. The interval and its invariance with respect to Lorentz transformations as a manifestation of the relationship between space and time. Light cone.

Elements of relativistic dynamics. Relativistic impulse, mass. Equation of motion of a relativistic particle. Relativistic expression for kinetic energy, total energy. Relationship between mass and energy. Dirac formula. Limits of applicability of classical mechanics.

Mechanics of Fluid and Gas. Basic equations of equilibrium and movement of liquids. Hydrostatics of incompressible fluid. Archimedes' law and its application. Barometric formula.

Kinematic description of fluid motion. Stationary flow of liquid and gases. Continuity equation. Bernoulli's equation. Leakage of liquids from the hole. Formula Torricelli. Stationary fluid flow through a straight pipe. Poiseuille's formula.

Viscosity. Laws of hydrodynamic similarity. Numbers of Reynolds, Froude, Mach, Strouhal. Turbulence and hydrodynamic instability. D'Alembert's paradox. Rip currents.

Movement of bodies in liquids and gases. Stokes formula. Lifting force of an airplane wing. Magnus effect.

Section 2.2. MOLECULAR PHYSICS

Temperature. Temperature and thermodynamic equilibrium. Empirical temperature scales. Ideal gas temperature scale. International practical temperature scale.

Laws of ideal gases. Equation of state and its consequences for infinitesimal processes. Macroscopic parameters.

The first **beginning of thermodynamics.** Quasi-tastic processes. Macroscopic work. The first law of thermodynamics for a system in an adiabatic shell. Mathematical formulation of the first law of thermodynamics. Heat capacity.

Internal energy of an ideal gas. Joe Ul's Law. Robert Mayer's equation. Adiabatic process. Poisson's equation. Speed of sound in gases. Bernoulli's equation. The speed of gas flow from the hole.

Second law of thermodynamics. Reversible and irreversible processes. Carnot cycle and Carnot's theorem.

Thermodynamic temperature scale. Identity of the thermodynamic temperature scale with the scale of an ideal gas thermometer.

inequality. Entropy. Law of increasing entropy. Generalization of the concept of entropy to nonequilibrium processes. Increase in entropy during gas diffusion. Gibbs' paradox.

Thermodynamic functions. Thermodynamic theory of the Joule - Thomson effect. Maximum work and free energy. General criteria for thermodynamic stability. Le Chatelier's principle and stability of thermodynamic equilibrium.

Thermal conductivity. Heat equation. Uniqueness theorem. The principle of temperature superposition. Temperature waves. External heat transfer.

The simplest questions of the molecular kinetic theory of matter. Gas pressure from the point of view of molecular kinetic theory. Velocities of thermal motion of gas molecules. Molecular - kinetic meaning of temperature. Distribution of energy by degrees of freedom.

Classical theory of heat capacity of ideal gases. Adiabatic heating and cooling of gases from the point of view of molecular kinetic theory.

Statistical distributions. Distribution of velocities of gas molecules. Maxwell's law of velocity distribution. Average velocities of molecules. The principle of detailed equilibrium. Experimental verification of Maxwell's velocity distribution.

Boltzmann's distribution law. Perrin's work on the definition of Avogadro's constant. Boltzmann distribution and planetary atmospheres.

Entropy and probability. Fluctuations. The most probable distribution method in Boltzmann statistics. Fermi - Dirac, Bose-Einstein statistics. Nernst's theorem. Einstein's quantum theory of heat capacity.

Transport phenomena in gases. Average free path. Effective section. Attenuation of a beam of molecules in a gas. Self-diffusion in gases. Relationship between diffusion and particle mobility. Concentration diffusion in gases.

Brownian motion as a diffusion process. Thermal diffusion in gases. Phenomena in rarefied gases. Molecular flow of ultra-discharged gas through a straight pipe.

Real gases. Molecular forces and deviations from the laws of ideal gases. Van der Waals equation. Van der Waals gas isotherms. Isotherms of real gas. Maxwell's rule. Continuity of gaseous and liquid states of matter. Properties of a substance in a critical state.

Surface tension. Thermodynamics of surface tension. Laplace's formula. Capillary-gravity waves of small amplitude.

Phase equilibria and phase transformations. Solutions. Phases and phase transformations. Conditions for phase equilibrium of a chemically homogeneous substance. Clapeyron - Clausius equation. Evaporation and condensation. Melting and crystallization. Dependence of saturated vapor pressure on temperature. Triple points. Status diagrams.

Boiling and overheating of liquid. Dependence of saturated vapor pressure on the curvature of the liquid surface. Metastable states. Phase transformations of the second kind. Convective stability of liquids and gases

Solubility of bodies. Osmosis and osmotic pressure. Raoult's law. Raising the boiling point and lowering the freezing point of a solution. Phase rule. Phase diagrams of binary mixtures.

Section 2.3. ELECTRICITY AND MAGNETISM

Electrostatics. Electric charge. Law of conservation of electric charge. For the pendant. Electric field strength and potential. The principle of field superposition and its application.

The Ostrogradsky-Gauss theorem for the electrostatic field in vacuum.

Electric field in a dielectric medium. Polarization of dielectrics. Ostrogradsky-Gauss theorem for the electric field in a medium. Conditions for the electrostatic field at the interface between two isotropic dielectric media.

Conductors in an electric field. Distribution of charges in a conductor. Electrical capacity. Capacitors.

Electric field energy. Electric field energy density.

Constant electric current. Classical electronic theory of electrical conductivity of metals. Ohm's and Joule -Lenz's laws in differential and integral forms.

Difference, voltage, EMF. Kirchhoff's rules and their applications. Difficulties of the classical theory of electrical conductivity of metals.

Electric current in gases. Non-self-sustaining and independent gas discharges. Glow discharge. Plasma. Debye radius.

Electric current in a vacuum. Electric current in liquids. Faraday's laws for electrolysis.

Electromagnetism. Magnetic field of current. Flux invariance of the electric field strength vector. Converting fields. The relative nature of the electric and magnetic components of the electromagnetic field.

Magnetic field of a single moving charge. Superposition principle. Biot-Savart - Laplace law.

Law of total current. The Ostrogradsky - Gauss theorem for a magnetic field in a vacuum. The work of moving a conductor with current in a magnetic field.

Movement of charged particles in an electromagnetic field. Lorentz force. Accelerators of charged particles. β - and mass spectrometers. Hall effect.

The effect of a magnetic field on a conductor and a current-carrying frame.

Electromagnetic induction. Faraday's experiments. Law of electromagnetic induction.

Mutual induction. Self-induction. Energy and energy density of the electromagnetic field.

Currents when closing and opening an electrical circuit.

Magnetic field in matter. Magnetic moment of an atom. Types of magnets. Elementary theory of diamagnetism. Paramagnetism. The law of total current for the magnetic field in matter.

Ferromagnetism. Magnetization curve. Hysteresis loop. Conditions for the magnetic field at the interface between two isotropic media.

Fundamentals of Maxwell's theory. Bias current. The complete system of Maxwell's equations. Energy and energy flow of the electromagnetic field. Umov - Poynting vector.

Electromagnetic oscillations and waves. Free harmonic oscillations in an oscillatory circuit (undamped and damped). Forced electromagnetic oscillations. Alternating current. Kirchhoff's laws for alternating current.

Electromagnetic waves. Energy of electromagnetic waves. Reflection and refraction of electromagnetic waves at the interface between dielectric media. Skin - effect. Doppler effect. Emission of electromagnetic waves by a dipole antenna.

Section 2.4. OPTICS

subject. Basic laws of optics. The evolution of ideas about the nature of light. The main stages in the development of optical theories.

Photometric concepts and units. Brightness and illumination of the optical image. Perception of light by the eye.

Interference of light. Coherence. Wave interference. Implementation of coherent waves in optics. Classical interference experiments. Influence of the size of light sources. Spatial coherence. The influence of non-monochromatic light.

Localization of interference fringes. Colors of thin plates. Newton's rings. Interference in thin plates and films. Stripes of equal slope. Interference devices (Jamin, Michelson) and the application of interference.

Diffraction of light. Diffraction in parallel rays. Huygens-Fresnel principle. Fresnel zones. Fraunhofer diffraction from a slit. Effect of slit width on the diffraction pattern. Effect of light source size. Diffraction grating.

Polarization of light. Natural and polarized light. Polarization by reflection and refraction. Polarization by birefringence. Malus's law. Finding ordinary and extraordinary rays in uniaxial crystals. Biaxial crystals. Polarization devices.

Interference of polarized rays. Elliptical and circular polars for tion. A crystal plate between two polarizers. Artificial birefringence. Birefringence in an electric field. Rotation of the plane of polarization. Magnetic rotation of the plane of polarization.

Molecular optics. Dispersion of light. Fundamentals of dispersion theory. Absorption of light. Spectral line width and radiation attenuation.

Action of light. Photoelectric effect. Laws of the photoelectric effect. Einstein's equation. Light quantum hypothesis. Internal photo effect.

The Compton phenomenon. The essence of the Compton phenomenon and its laws. The theory of the Compton phenomenon. Doppler effect.

Thermal radiation. Laws of heat and radiation. Kirchhoff's law. Absolutely black body. Radiation from non-black bodies. Stefan-Boltzmann law. Wien's law of displacement. Planck 's radiation formula.

Lasers, nonlinear optics. And the emission of electromagnetic waves by a set of coherent sources. Absorption and amplification of radiation propagating in a medium. Operating principle of an optical quantum generator. Continuous helium-neon laser.

Section 2.5. PHYSICS OF VOLUME AND ATOMIC PHENOMENA

Development of atomistic concepts. Orders of magnitude of distances and energies for atomic-molecular and nuclear processes. Specificity of the laws of the microworld. Nuclear model of the atom.

Development of quantum concepts. Quantization of the energy of matter and energy and radiation. Bohr 's postulates on stationary states and radiation frequencies during quantum transitions. Bohr's atomic model. The correspondence principle and its application to the hydrogen atom. Bohr-Sommerfeld quantization rules. Magnetic properties of atoms. Spin.

Wave-particle duality. Corpuscular properties of radiation. Louis de Broglie 's hypothesis. Electron diffraction of atoms, molecules, neutrons. Properties of Louis de Broglie waves. The need for a probabilistic interpretation of quantum phenomena.

Quantum mechanical description of atomic systems. The concept of a quantum state and its characterization using the wave function. Probabilistic interpretation of the wave function. Difference between quantum mechanical and classical descriptions of motion. Superposition principle.

Uncertainty relationship. Time and stationary Schrödinger equations. Selection rules.

The simplest one-dimensional problems of quantum mechanics. Rectangular potential well and harmonic oscillator. Rectangular potential barrier. Tunnel effect. Energy levels at two and many potential energy minima.

Quantum mechanics of a system of identical particles. Symmetrical and asymmetrical wave functions. Bosons and fermions. The concept of the Bose-Einstein distribution and the Fermi-Dirac distribution. Pauli's principle.

Hydrogen atom. Properties of centrally symmetric systems. Energy levels and quantum numbers. Degeneration. Type of wave functions and probability density distribution. Spectra of the hydrogen atom and hydrogen-like atoms. Spinorbital interaction and fine structure. Ultrafine structure.

Multielectron atoms. Approximate characterization of individual electrons by quantum numbers n And l. The concept of electronic configuration. Electronic shells of the atom and their filling. Physical explanation of the periodic law. Interactions of electrons in multielectron atoms.

X-ray and X-ray photoelectron spectra and their nature. Energy levels and spectrum of the helium atom. Vector addition of angular momentum and types of connections. Hunda Rules.

Structure and properties of molecules. Types of motion in a molecule. Adiabatic approximation. Potential energy curves and surfaces. Equilibrium configuration of the molecule. The shape and size of molecules, the symmetry of their equilibrium configurations. Electronic states of molecules. Electronic shells and chemical bonds in diatomic and polyatomic molecules. Directional valence. Spectra of molecules.

Atoms and molecules in external fields. E Zeeman effect. Paschen-Buck effect. Magnetic resonance. Electron paramagnetic resonance. Nuclear magnetic resonance. Electrical resonance.

Quantum properties of solids. Periodicity of potential and one-electron wave functions for a crystal lattice. Formation of zones. Excited electronic states of a crystal and the concept of electrons. Vibrational states of a crystal and the concept of photons.

Filling energy zones. Band models of metals, semiconductors, dielectrics. Conductivity of solids. Intrinsic and impurity conductivity. Semiconductor diode. Ferromagnetism and antiferromagnetism.

Elementary processes in gases and plasma. Processes of excitation, ionization, dissociation, recombination, charge exchange. Types of interactions in plasma. Establishing equilibrium in gases and plasma.

Nonequilibrium radiation. Types of nonequilibrium radiation. Luminescence. Spontaneous and stimulated radiation. Conditions for the occurrence of lasing in lasers and masers.

Section 2.6. PHYSICS OF THE NUCLEUS AND ELEMENTARY PARTICLES

Basic characteristics of the atomic nucleus and its composition. Characteristics of the proton and neutron. Isotopes. Isobars, isomers. Stable and radioactive nuclei. Spin and magnetic moment of the nucleus. Electric dipole and quadrupole moments of the nucleus. Bosons and fermions. Pauli's principle.

Mass defect and binding energy of the nucleus. Nature and properties of nuclear forces. Electric field of the nucleus and nuclear forces. Meson theory of nuclear forces.

Radioactivity. Types of radioactive radiation. Statistical nature of decay. Law of radioactive decay. Radioactive equilibrium and units of radioactivity. Artificial radioactivity. Dosimetry of ionizing radiation. Dose units s.

α decay. β-decay. γ - radiation from nuclei.

Fundamental structure and physical principles of operation of a nuclear reactor. Reactors with slow, fast and intermediate neutrons; homogeneous and heterogeneous reactors. Nuclear energy.

Thermonuclear reactions. Basic physical conditions for the implementation of a chain reaction of thermonuclear fusion. Main directions in the implementation of controlled thermonuclear fusion.

Interaction of nuclear radiation with matter and methods of recording nuclear radiation. Interaction of charged particles and neutrons with matter. Slowing down neutrons. Passage of □-radiation through matter. Dependence of the effective cross sections of the main mechanisms of interaction of □-quanta on their energy and on the properties of the substance. Vavilov-Cherenkov radiation.

Elementary particles. Cosmic radiation. Primary and secondary cosmic rays. Origin hypotheses. " Soft " and " hard " components of secondary cosmic radiation, their nature. The passage of cosmic radiation through the atmosphere. Earth's radiation belts.

Elementary particles. Classification of elementary particles. Leptons, hadrons, gauge bosons. Particles and antiparticles, the phenomenon of annihilation. Mechanisms of interaction in the world of elementary particles. Feynman diagrams. Conservation laws governing particle transformations.

Classification of interactions. Electromagnetic interaction. Basic quantum electrodynamic processes. Electromagnetic processes involving hadrons.

Strong interactions and structure of hadrons. Quarks and gluons. Quark structure of mesons and baryons. A new quantum characteristic of quarks and gluons is color. Basic processes involving hadrons.

Weak interactions. The universality of weak interaction. The carriers of the weak interaction are intermediate bosons. Weinberg-Salam model. The main types of transformations of elementary particles caused by weak interaction.

Discrete symmetries C, P, T and the CPT theorem. Isotopic and color symmetry. Gauge invariance as a principle for constructing field theories of elementary particles. The problem of constructing a unified theory of weak, electromagnetic and strong interactions.

Section 2.7. CLASSICAL MECHANICS AND FUNDAMENTALS OF CONTINUUM MECHANICS

Introduction. Subject of classical mechanics. Basic concepts and models of classical mechanics.

The principle of virtual movements. Virtual movements. Variations of coordinates and functions. Generalized coordinates. Specifying the movement of a point in generalized coordinates.

D'Alembert's principle. Lagrange equation. The principle of virtual work. D'Alembert's principle. Expression of generalized forces through projections of forces onto the fixed axes of the Cartesian coordinate system.

Lagrange function. Examples of constructing the Lagrange function: free material point, system of free material points.

Lagrange equations for potential and non-potential forces. Invariance of Lagrange equations with respect to transitions to non-inertial reference systems. Coriolis force. Principle of least action.

Laws of conservation and symmetry of space and time. First integrals of motion. Hamilton function of the system. Conservation laws corresponding to fundamental symmetries: energy, momentum, angular momentum.

Hamilton's canonical equations. Hamilton's formalism. Hamilton's canonical equations. First integrals of Hamilton's equations. Equivalence of Lagrangian and Hamiltonian formalisms. Rouss function.

Poisson brackets and their algebraic properties. Fundamental Poisson brackets. Connection between Poisson brackets and first integrals of motion.

Integration of equations of motion. Movement in a homogeneous field. The case of one degree of freedom. Period as a function of energy. Two body problem. Reducing the problem to an equivalent problem for one body. Reduced mass.

Movement in the central field. Equations of motion and first integrals. Qualitative analysis of movement trajectories and their parameters. Keplerian problem. Parametric equation. Kepler's laws. Calculation of speed at various points in the orbit.

Movement of particles in a Coulomb field of repulsive force. Particle scattering. Rutherford's formula.

Small vibrations of mechanical systems. Free one-dimensional vibrations. Small vibrations of systems with several degrees of freedom. Normal coordinates.

Forced vibrations. Resonance. Forced vibrations taking into account friction.

Damped oscillations. Dissipative function. Anharmonic vibrations. The case of expansion of the Lagrange function (potential energy) to third-order terms. Damped oscillations with several degrees of freedom.

Movement of a rigid body. Angular velocity. Euler angles. Euler's kinematic equations.

Inertia tensor. Main axes of inertia. Reducing the inertia tensor to diagonal form. Ellipsoid of inertia. Momentum of impulse, its representation through the components of the inertia tensor. Expression of kinetic energy through the components of the inertia tensor.

Equations of rotational motion of a body. Euler's dynamic equations. Equations of motion of a body with a pole at any point.

Fundamentals of continuum mechanics. Subject and methods of continuum mechanics. Main hypotheses. Elements of tensor calculus.

Deformation theory. Theorems of Stokes and Gauss – Ostrogradsky.

Continuity equations. Equations of motion of a continuous medium. Ideal liquid and gas. Linear elastic body and linear viscous fluid.

Section 2.8. ELECTRODYNAMICS

Introduction. Vector analysis operations. Integral and differential formulas of vector analysis. Equation of force lines. Dirac delta function and examples of its application.

Fundamental interactions. Interaction in mechanics and electrodynamics.

Vectors of electric and magnetic fields. Classification of environments. Graphic representation of fields.

Basic equations of electrodynamics. Maxwell's equations. Continuity equation. Ohm's law in differential form.

Vector and scalar potentials. Lorentz condition. Equation for potentials. Gauge invariance. Magnetic field induction $\boldsymbol{B}$ and vector potential $\boldsymbol{A}$. Vector potential and quantum mechanics.

Conductors and dielectrics in the light of Maxwell's equations. Classification of electromagnetic phenomena. Maxwell's equations and extraneous currents.

Conditions at the interface. Complete system of boundary conditions. Boundary conditions on the surface of an ideal conductor. Physical essence of boundary conditions.

Electromagnetic field. Electromagnetic field energy. Balance and energy density of the electromagnetic field. The speed of propagation of electromagnetic energy.

Electromagnetic waves. Wave equations. Solutions of Maxwell's equations in empty space. Waves in a vacuum. Plane, three-dimensional, spherical waves.

Solutions of Maxwell's equations with currents and charges. Light and electromagnetic waves. Spherical waves from a point source. Fields of an oscillating dipole. Potentials of a moving charge, general solution of Liénard and Wiechert. Potentials of a charge moving at a constant speed; Lorentz formula.

Special theory of relativity. Postulates of SRT. Lorentz transformations. The interval between events and its invariance. The relativity of simultaneity. Relativity of lengths in different ISOs. Duration of events in different SOs.

Dynamics of service station. The basic law of relativistic mechanics of a material point. Relativistic expression for kinetic energy. Relationship between mass and energy. System binding energy.

The concept of general relativity. The principle of equivalence. Astrophysics.

Four-dimensional representation of the kinematics and dynamics of SRT. World point. Lorentz transformations for a 4-vector. Relativistic action function for a free particle. 4-momentum vector for a free particle. Relationship between momentum and energy.

Relativistic electrodynamics. Action function for electric charge in space-time. 4-vector of electromagnetic field potential. Lagrange function in an electromagnetic field. Momentum and energy of an electron in an electromagnetic field. Hamilton function in an electromagnetic field. Differential equations of electron motion in space-time. Electromagnetic field tensor. Electromagnetic field tensor matrix. Law of conservation of electron energy in an electromagnetic field.

Relativistic transformation of fields. Invariants of the electromagnetic field. Lorentz transformations for projections of vectors $\boldsymbol{E}$ and $\boldsymbol{B}$. 4-vector of current density. Four-dimensional form of Maxwell's equations.

Field energy of a point charge. Field impulse of a moving charge. Electromagnetic mass.

Section 2.9. QUANTUM THEORY

Introduction. Early quantum theory. The main stages of creating a strict quantum theory.

Basic definitions and concepts of quantum physics. Quantum system, quantum state. The principle of correspondence. Wave function and its statistical interpretation (Postulate 1). The principle of superposition of states. L. de Broglie wave, wave packet (P. Dirac delta function). Quantum ensemble. Uncertainty relationship. The principle of complementarity. Wave packet reduction. Stern-Gerlach experiments.

Quantum average values of physical quantities. Operators of coordinates and momentum. Operators of observables (linear Hermitian operators) (Postulate 2). Hilbert space and its basic properties. Functions from operators. Eigenfunctions and eigenvalues of linear Hermitian operators. Orthonormal basis. A complete description of the state and a complete system of commuting operators of observable quantities. The number of degrees of freedom of a quantum system. Uncertainty relationship. Minimizing wave packets.

Pure and mixed states. Density matrix and its properties. Expressing the average value of the observed density through a density matrix. Wave packet reduction (projection postulate).

Evolution of states over time (second group of postulates). Postulate 3 - wave equation (Schrodinger equation). Continuity equation (probability current density). Construction of a quantum Hamiltonian based on the classical one. Stationary states and their properties. The problem of a potential well of finite depth. Integrals of motion. Evolution of states described by the density matrix. Evolution operator and its properties. "Representation" of Schrödinger, Heisenberg and the interaction.

The concept of the state vector of a system (the space of P. Dirac state vectors). Representation of state vectors. Basic operators. Secular equation, equivalence of solving the equation for eigenvalues and diagonalizing the operator matrix (method of canonical transformations). Transformations of state vectors and operators when moving from one basis to another. Properties of unitary transformations.

Harmonic oscillator. Creation and annihilation operators and their properties. Expression of the oscillator Hamiltonian through the creation and annihilation operators, its eigenfunctions and eigenvalues. Representation of fill numbers.

The relationship between quantum and classical theory. Ehrenfest's theorem. The ultimate transition from quantum mechanics to classical mechanics. Semiclassical approximation (Wentzel-Kramers-Brillouin approximation). Bohr-Sommerfeld quantization rule.

Approximate methods of quantum mechanics. Perturbation theory. Disturbances independent of time. Stark effect.

Angular momentum operator. Its own functions and meanings. Properties of spherical functions. Angular momentum. Raising and lowering operators and their properties. Spin. Pauli matrices. Matrix representation of operators. Spinors. Rules for adding angular momentum. Clebsch-Gordan coefficients.

"Two-body problem." Motion of a particle in a central potential field of forces. Hydrogen atom. Wave functions and energy values of stationary states of the hydrogen atom. Quantum numbers and their physical meaning.

Direct variational method (Ritz method). Calculation of energies and wave functions of states of a hydrogen atom and a harmonic oscillator using the variational method.

Quantum theory of systems consisting of identical particles. The principle of identity. Properties of the wave function of a system of non-interacting particles. Pauli's exclusion principle. Fermions and bosons. Exchange degeneracy. System of two particles with spin. Jung's schemes.

Helium atom. Para- and orthohelium. Exchange integral.

Multielectron atoms. Approximation of the central field. Shell model of the atom and statistical method (Thomas-Fermi).

Quantum theory of molecules. Schrödinger's equation for a molecule (adiabatic approximation). Nuclear and electron problems for a molecule. Hydrogen molecule. Heitler-London method (variational method). Chemical bond energy.

Scattering theory (collision theory). One-dimensional motion (scattering at a potential barrier). Tunnel effect. Stationary scattering theory. Scattering amplitude and effective differential scattering cross section. Equation for scattering amplitude. Born approximation.

Theory of quantum transitions. Quantum transitions under the influence of external time-dependent perturbation. Disturbance. The probability of transition from one state to another.

Limitations of nonrelativistic quantum theory. P. Dirac's equation for a free particle.

Section 2.10. THERMODYNAMICS AND STATISTICAL PHYSICS

Introduction. A brief outline of the development of thermodynamics and molecular kinetic theory.

Basic laws and methods of thermodynamics. Thermodynamic system. Thermodynamic parameters. Postulates of thermodynamics. Internal energy of the system. Energy exchange; work and warmth.

Equations of state (caloric and thermal) of the system. The number of degrees of freedom of a thermodynamic system. Examples of equations of state. Thermal coefficients and the relationship between them.

The first law of thermodynamics and its equation. Heat capacity and its properties as a function of the process. Relationship between heat capacities in isoprocesses. R. Mayer's equation. Equations of basic thermodynamic processes. Differential polytropic equation for a simple system in various variables. Relationship between elastic moduli and heat capacities.

Second law of thermodynamics. Inequality of transformation of heat into work and work into heat. Reversible (quasi-static) and irreversible processes. The principle of adiabatic unattainability and the second law of thermodynamics for equilibrium processes. The existence of a unique state function - entropy and thermodynamic temperature (thermodynamic temperature scale). Mathematical justification for the existence of entropy. The Clausius equality as an integral equation of the second law for equilibrium circular processes. Basic equation of thermodynamics for equilibrium processes. Gibbs' theorem on the entropy of a gas mixture (Gibbs' paradox).

Second law of thermodynamics for nonequilibrium processes. Clausius inequality for a nonequilibrium circular process and its physical meaning. Basic equation and basic inequality of thermodynamics. The first and second theorems of S. Carnot. Ideal heat engine and efficiency Carnot cycle. Limits of applicability of the second law of thermodynamics.

Third law of thermodynamics. Some consequences of the third law of thermodynamics (unattainability of 0 K, behavior of thermal coefficients at $T \rightarrow 0$ K, calculation of entropy and behavior of heat capacities at $T \rightarrow 0$ K, degeneracy of an ideal gas).

Methods of thermodynamics. Cases of using the method of thermodynamic potentials for simple systems. Characteristic functions for independent variables: S, V ; V, T; T, p ; S, p , etc.

Helmholtz free energy and Gibbs energy. Enthalpy and internal energy.

Derivatives of thermodynamic potentials and their physical meaning. Joule-Thomson process and gas liquefaction. Maxwell's reciprocity relations. Gibbs-Helmholtz equation. Thermodynamic potentials of complex systems.

Thermodynamic potentials of systems with a variable number of particles. Chemical potential and its physical meaning. Large thermodynamic potential. Gibbs-Duhem equation.

Conditions for equilibrium and stability of thermodynamic systems. General conditions of equilibrium and stability.

Equilibrium conditions for a two-phase one-component system. Condition for the stability of equilibrium of a homogeneous system. General conditions for thermodynamic equilibrium and stability of a homogeneous system. Le Chatelier-Brown principle.

Equilibrium in a homogeneous system. Condition of chemical equilibrium (law of mass action, constant of chemical equilibrium). Equilibrium in nonideal systems.

Equilibrium in a heterogeneous system. Equilibrium condition for a heterogeneous system. Gibbs phase rule. Thermodynamic degrees of freedom of a heterogeneous system. Phase equilibrium curves. Triple point. Equilibrium of binary systems. Basic equation of the theory of equilibrium of binary systems.

The role of surface effects in the formation of a new phase. Surface tension coefficient. Laplace pressure. Metastable states of a homogeneous system during first-order phase transitions. Embryos of a new phase. Critical radius for the onset of steam condensation.

Phase transitions. Classification of phase transitions. Phase transitions of the first order. Clapeyron-Clausius equation. Dependence of saturated vapor pressure above the condensed phase on temperature.

Phase transitions of the second order. Ehrenfest equation. Features of the thermodynamics of the superconducting transition in the absence of a magnetic field and in its presence.

Critical phenomena. Criteria for stability of a critical state and their analysis. Supercritical phenomena.

Basic principles of statistical physics. Microscopic and macroscopic states of a many-particle system. The main task of statistical physics. Description of motion in classical mechanics. Canonical equations of motion. Conservative systems. Integrals of motion.

Poisson brackets. Statistical ensemble. Phase probability density and its normalization. Liouville's theorem (equation).

Microcanonical ensemble. Postulate about equal a priori probability of any microstate of an equilibrium isolated system and microcanonical distribution. Entropy (statistical definition).

Canonical distribution. Statistical integral of the system. Helmholtz free energy. Internal energy of a statistical system. Configuration integral and configuration distribution. Calculation of entropy through the canonical distribution.

Large canonical distribution. Large statistical integral and large thermodynamic potential. Thermodynamic equivalence of canonical Gibbs distributions.

Fundamentals of quantum statistics. Description of quantum systems. Density operator (matrix). Evolution of the density matrix with time (Neumann equation). Quantum microcanonical distribution. Statistical sum. Quantum grand canonical distribution. The classical limit of quantum statistics.

Classical monatomic ideal gas. Maxwell-Boltzmann distribution. Statistical integral, Helmholtz energy of an ideal gas. Equations of state, entropy and chemical potential.

Quantum monatomic ideal gases. Two quantum statistics (Bose-Einstein and Fermi-Dirac distributions). Large thermodynamic potential of quantum ideal gases. Thermal equations of state of quantum ideal gases.

Weakly degenerate quantum gases. Highly degenerate electron gas. Degenerate Bose gas. Bose-Einstein condensation.

Bogolyubov's method. Chain of Bogolyubov integro-differential equations for equilibrium distribution functions.

Theory of classical nonideal systems. Bogolyubov's method in the theory of gases.

Oscillator and rotator in the thermostat. Theory of heat capacity of diatomic gases. Statistical theory of equilibrium radiation. Dulong-Petit law. Einstein and Debye's theory of the heat capacity of a solid.

Theory of equilibrium fluctuations. Calculation of fluctuations by the Gibbs method. Critical opalescence. Calculation of fluctuations using the distribution function method. Quasi-thermodynamic theory of fluctuations.

Fundamentals of nonequilibrium thermodynamics. Local thermodynamic equilibrium and the basic equation of thermodynamics of nonequilibrium processes. Entropy production. Balance equations and conservation laws. Flows and thermodynamic forces. The production of entropy during chemical reactions in a system.

Thermodynamics of linear irreversible processes. Onsager reciprocity relations. Curie's principle. Variational principles of thermodynamics of irreversible processes. Onsager's variational principle.

Random variables and processes. Markov processes. Smoluchowski equation. Fokker-Planck equation. Diffusion of a Brownian particle (Einstein's relation).

Chain of Bogolyubov equations for nonequilibrium distribution functions of classical systems. Hierarchy of time scales and abbreviated description of a nonequilibrium system at various stages of its evolution.

Boltzmann kinetic equation. The collision integral and its properties. Collision invariants. Methods for solving the Boltzmann kinetic equation (relaxation approximation).

3. GRADING SCALE AND MINIMUM NUMBER OF POINTS CONFIRMING SUCCESSFUL COMPLETION OF THE ENTRANCE TEST

The competitive entrance test is conducted in written form. The task for the entrance test is determined by a task sheet containing test tasks.

The results of the competitive entrance test are determined using a 100-point system: each test task is a test task with four answer options and is worth 5 points. In total, the task sheet contains 20 tests, 5 tests from each discipline submitted for the entrance test.

A comparison of the national and 100-point rating scales is presented in the following table.

Level competence	Grade By national scale	Sum of points according to 100 points scale
High (creative)	Great	81-1 00
Sufficient (constructive-variable)	Fine	51-80
Average (reproductive)	Satisfactorily	25-50
Short (receptive-productive)	Unsatisfactory	0-24

The minimum number of points confirming successful completion of the entrance test is 25.

The minimum passing score for studying at the expense of federal budget allocations is determined on a competitive basis by the Admission Rules of Sevastopol State University.

4. LIST OF RECOMMENDED LITERATURE FOR PREPARING FOR THE ENTRANCE TEST

Main literature:

1. Sivukhin, D.V. General course in physics: textbook / Sivukhin D.V. – Moscow: FIZMATLIT, 2008. - 784 p.
2. Savelyev I.V. General physics course: textbook: in 3 volumes / I.V. Savelyev. - 15th ed., erased. - St. Petersburg: Lan, [b. G.]. - Volume 1: Mechanics. Molecular physics - 2019. - 436 p.

Additional literature:

1. Trofimova T.I. Physics course: textbook for engineering and technical specialties of universities / T.I. Trofimova. - 8th edition, stereotypical. - Moscow: Higher School, 2004. – 541 p.

To section 2

Main literature:

1. Savelyev I.V. General physics course: textbook: in 3 volumes / I.V. Savelyev. - 15th ed., erased. - St. Petersburg: Lan, [b. G.]. - Volume 1: Mechanics. Molecular physics - 2019. - 436 p.

Additional literature:

1. Matveev A.N. Molecular physics: Textbook. manual for universities. - M.: Higher School, 1981. - 400 p.

To section 3

Main literature:

1. Savelyev I.V. General physics course: textbook: in 3 volumes / I.V. Savelyev. - 15th ed., erased. - St. Petersburg: Lan, - Volume 2: Electricity. Magnetism - 2019. - 496 p.
2 Kann K.B. General physics course: textbook / K.B. Cannes. - Moscow: COURSE: INFRA-M, 2018. - 360 p. 3. Matveev A.N. Electricity and magnetism Textbook. manual for universities. - M.: Higher School, 1983. - 463 p.
3. Detlaf A.A., Yavorsky B.M. Physics course. - M.: Higher. school, 1989.- 608 p.

Additional literature:

1. Giancoli D. Physics. T. 1: M.: Mir, 1989. - 656 p.

To section 4

Main literature:

1. Savelyev I.V. General physics course: textbook: in 3 volumes / I.V. Savelyev. - 15th ed., erased. - St. Petersburg: Lan, - Volume 2: Electricity. Magnetism 2019. - 496 p.
2. Sivukhin D.V. General physics course. Optics. Textbook - M.: Nauka, 2008. - 752 p.

Additional literature:

1. Butikov E.I. Optics: Textbook. manual for universities / Ed. N.I. Kaliteevsky. - M: Higher. school, 1986. - 512 p.
2. Detlaf A.A., Yavorsky B.M. Physics course. - M.: Higher. school, 1989. - 608 p.

To section 5

Main literature:

1. Savelyev I.V. Course of general physics [in 3 volumes] – volume III Atomic physics; M. Science 1989 – 520 p.
2. Solid state physics. Ed. prof. Vereshchagin. M., Higher School; 2001– 32 p.
3. Atomic and nuclear physics. workshop edited by prof. Evstigneeva, Sevastopol, 2015.
Additional literature:
1. Trofimova T.I. Physics course: textbook for engineering and technical specialties of universities / T.I. Trofimova. - 8th edition, stereotypical. - Moscow: Higher School, 2004. – 541 p.

To section 6

Main literature:
1. Shirokov Yu.M., Yudin K.P. Nuclear physics (textbook), M., Nauka, 1980.
2. Irodov I.V. Collection of problems in atomic and nuclear physics, M., 2007.
Additional literature:
1. Rakobolskaya I.V. Nuclear Physics (Moscow State University Publishing House), 2016.

To section 7

Main literature :
1. Landau L.D., Lifshits E.M. Theoretical physics: Textbook. allowance. - In 10 volumes. T.1 Mechanics. - M.: Science. Ch. Ed. physics and mathematics Lit., 1988. - 216 p.
2. Landau L.D., Lifshits E.M. Theoretical physics: Textbook. allowance. - In 10 volumes. T.7 Theory of Elasticity. - M.: Nauka. Ch. Ed. physics and mathematics Lit., 1988. - 202 s.
Additional literature:
Landau L.D., Lifshits E.M. Theoretical physics : Textbook. allowance.- In 10 volumes. T.6. Hydrodynamics - M: Nauka, 2015 - 718 P.

To section 8

Main literature:
1. Kompaneets A.S. Theoretical physics. – Moscow: FIZMATLIT, 2008 – 563 p.: ill.
2. Irodov I.E. UDC. 583.3. Basic laws of electromagnetism: Textbook. manual for universities. – M.: Higher. school, 1983. – 279 p.; ill.
Additional literature:
1. Feynman R., Layton R., Sands M. UDC 530. Feynman lectures on physics. v.6. Electrodynamics. - M.: Mir., 1977. – 347 p.: ill.

To section 9

Main literature:
1. Landau L.D., Lifshits E.M. Quantum mechanics. - M., Fizmatgiz, 2004.
2. Blokhintsev D.I. Selected works, vol.1. - M., Higher. school, 2019.
3. Sokolov A.A. and others. Quantum mechanics [Textbook for physics. specialist. universities] - M., Nauka, 2017.
Guidelines and manuals:
1. Collection of problems in theoretical physics. Textbook for universities. Author: L.G. Grechko, V.I. Sugakov, O.F. Tomasevich, A.M. Fedorchenko Moscow: FIZMATLIT, 2008.

To section 10

Main literature :

1. Bazarov I.P. Thermodynamics. - M: Nauka, 2002. - 346 p.
2. Bazarov I.P. and others. Nonequilibrium thermodynamics and physical kinetics. - M.: Publishing house. MSU, 2019. – 239 p.

Additional literature :

1. Landau L.D., Lifshits E.M. Theoretical physics : Textbook. allowance. T.5, part 1 Statistical physics. - M: Nauka, 2017 - 584 p.