Entrance tests

PHYSICS

Mechanics

1. Kinematics of the rectilinear motion of a material point.
2. Kinematics of the curvilinear motion of a material point. Normal and tangential acceleration. Rotational motion of a material point. Angular velocity and angular acceleration.
3. Kinematics of a rigid body. Number of degrees of freedom. Communications. Absolutely solid body. Progressive, rotational and plane motion of a rigid body.
4. Force, mass, momentum, work and energy in Newtonian mechanics.
5. Inertial reference frames. Newton's dynamics laws.
6. Moment of momentum and moment of force. The equation of moments for a material point and a system of material points. The inertia tensor.
7. Conservation laws and their role in physics. The laws of conservation of momentum, angular momentum and total mechanical energy. Space-time symmetry and conservation laws.
8. Galilean transformations. Galilean relativity principle.
9. Postulates of the special theory of relativity. Lorentz transformations for coordinates and time. Consequences from the Lorentz transformations (relativity of simultaneity and the principle of causality, shortening of distances and slowing down of the moving clock). Space-time interval. Addition of velocities in the special theory of relativity. Equivalence of mass and energy.
10. Damped oscillations. Decrement of attenuation. Forced oscillations. Resonance.
11. Small oscillations. Harmonic oscillator. Equation of motion of a linear harmonic oscillator. Equation of harmonic oscillations. Phase portrait of a harmonic oscillator. Energy of oscillations.
12. Waves in elastic media. Longitudinal and transverse waves. Frequency, wavelength, dispersion law, velocity, polarisation. Wave packets. Phase and group velocities. Elements of acoustics. Plane and spherical waves.
13. The principle of least action. Lagrange function. Equations of motion in the form of Lagrange. Hamilton function. Equations of motion in the Hamiltonian form.

Molecular physics and thermodynamics

1. Internal energy, heat and work. The first law of thermodynamics.
2. Isoprocesses and gas laws based on the example of an ideal gas and Van der Waals gas. Application of the first law of thermodynamics to isoprocesses in an ideal gas.
3. Cyclic processes, thermal and refrigerating machines. Reversible and irreversible processes. The second law of thermodynamics.
4. Entropy. The second law of thermodynamics for non-equilibrium processes.
5. The third law of thermodynamics (Nernst heat theorem).
6. Internal energy, free energy, Gibbs potential, enthalpy. Thermodynamic potentials for the systems with variable mass. Chemical potential.
7. Conditions for the equilibrium of a two-phase single-component system. Conditions for stability of equilibrium of a single-phase system. Le Chatelier's principle.
8. Phase transitions of the first kind. The behaviour of thermodynamic quantities in phase transitions of the first kind. The Clausius-Clapeyron equation. Melting. Sublimation. Evaporation and boiling, saturated steam pressure.
9. Contact corner. Wetting. Capillary phenomena.
10. Metastable states. Triple point. Critical point. The Gibbs phase rule.

11. Phase transitions of the second kind. The behaviour of physical quantities in phase transitions of the second kind.

12. The phase space. The Gibbs ensemble (statistical ensemble). N-partial distribution function. The Liouville theorem.
13. Microcanonical distribution. The canonical Gibbs distribution.
14. Maxwell-Boltzmann distribution.
15. The large canonical Gibbs distribution.
16. Quantum statistics. Fermi-Dirac and Bose-Einstein distributions. General properties of Fermi gases and Bose gases.
17. Probability distribution of fluctuations (Gaussian distribution). Fluctuations in an ideal gas.
18. Kinetic Boltzmann equation for a rarefied gas.
19. Diffusion. The Fick's laws of diffusion.
20. Mechanisms of internal friction (viscosity) in gases, liquids and solids.
21. Mechanisms of thermal conductivity in gases, liquids and solids.
22. Electrical conductivity. The Drude-Lorentz formula for electrical conductivity.

Electricity and magnetism

1. Electric charge and its properties. The law of conservation of electric charge. Coulomb's Law.
2. Electric field. Electric field strength. Gauss's theorem.
3. Potentiality of the electric field of stationary charges. Potential of the field of point charge. Potential of the charge system.
4. Electric current. The magnetic field of the current. The Biot-Savart-Laplace law.
5. Faraday's law of electromagnetic induction. The Lenz rule.
6. Electrical resistance. Conductors. Ohm's law for a chain section.
7. Condenser in an alternating current circuit. Resistance of capacitor to alternating current (capacitive resistance).
8. Inductance in an alternating current circuit. Inductive resistance.
9. Electric circuits. The Kirchhoff's rules for constant and alternating currents.
10. AC circuit resistance. AC power.
11. Planar monochromatic electromagnetic waves and their basic properties (frequency and wave number, frequency relation with wave number (dispersion law), propagation velocity, field orientation). Transverse of electromagnetic waves.
12. Motion of a charge in an electric field. Motion of a charge in a magnetic field. The power of Lorentz.
13. Force acting on a conductor with a current in a magnetic field (Ampere force).
14. Magnetic moment of closed current. Interaction of the magnetic moment with the field.
15. Macroscopic electromagnetic fields in media. Maxwell's equations.
Material equations.
16. Dielectrics. Bound charges. Polarisation of dielectrics in an electric field. Vector polarization.
17. Electrical susceptibility (polarizability). Polar and nonpolar dielectrics. Features of their behaviour in constant and variable fields.
18. Magnetic properties of matter. Magnetization vector. Molecular currents. Dia-, para- and ferromagnets.
19. The nature of diamagnetism. Larmor's theorem. Diamagnetism of Landau.
20. The nature of para- and ferromagnetism.
21. Superconductivity. Electrical and magnetic properties of superconductors. High-temperature superconductivity.

Optics

1. The laws of geometric optics. Constructing images in collecting and dispersing thin lenses.
2. Basic photometric quantities, light flux, light intensity, brightness, luminosity, illumination, light intensity.

3. Electromagnetic nature of light. Polarisation, types of polarisation of a light wave. Polarisers.
4. Interference of light, Two-beam and multi-beam interference. Coherence.
5. Diffraction. The Huygens-Fresnel principle. Fresnel diffraction. Fresnel diffraction on round holes and obstacles. Fresnel zones.
6. Spectral devices. Characteristics of spectral devices. Diffraction grating and Fabry-Perot interferometer. Spectroscopy.
7. Diffraction of light on multidimensional structures. X-ray diffraction.
8. The classical physical model of light emission. The natural width of the spectral line. Forms of the spectral line. Spectral line broadening.
9. Kirchhoff's laws for thermal radiation. Absolutely black body and the laws of its radiation. Spectral radiation density.
10. Quantum physical model of light emission. Planck's formula for the emission of an absolutely black body. Spontaneous and stimulated emission of light by atoms.
11. The photoelectric effect, the laws of photoelectric effect. Einstein's formula for the photoelectric effect.
12. The Compton effect and explanation of it.
13. The sources of coherent radiation are lasers. Active environment. The concept of negative temperature. Lasers and non-linear optics.
14. Reflection of light from the interface of two isotropic media, Fresnel theory, Brewster angle.
15. Anisotropic media. Propagation of light in an anisotropic medium. Fresnel equation. Birefringence. Application of the birefringence phenomenon. Optical activity.
16. Dispersion of light. The electronic theory of light dispersion. Normal and anomalous dispersion. Absorption of light.
17. Scattering of light, Rayleigh light scattering.

Atom physics and quantum mechanics

1. Radiation of an absolutely black body. Quantum Planck hypothesis. Quantum of light. The Planck constant.
2. Classical ideas about the structure of the atom, their inconsistency. Hydrogen atom according to Bohr.
3. Corpuscular-wave dualism. Waves of de Broglie.
4. Heisenberg's uncertainty principle, its heuristic value.
5. Wave function, its statistical interpretation. Principle of superposition.
6. Matrix mechanics of Heisenberg. Operators in quantum mechanics. The concept of measurement. The mean value of the physical quantity.
7. The Schrodinger equation, its stationary solutions. Properties of stationary states.
8. Symmetry and conservation laws in quantum mechanics.
9. The harmonic oscillator.
10. Motion of a particle in a central field. Spatial rotator.
11. Non-relativistic theory of the hydrogen atom.
12. Stationary perturbation theory. The non-degenerate level. Degenerate level.
13. Quantum transitions, transition probability. The 'golden' Fermi rule.
14. Law of conservation of energy and the ratio of energy-time uncertainties.
15. Selection rules for electric dipole radiation and absorption. X-ray electron spectroscopy.
16. Resonance methods for studying substances (EPR, NMR etc.).
17. The problem of identical particles in quantum mechanics. The Pauli principle. Permutation symmetry of wave functions.
18. The helium atom. The structure of many-electron atoms.
19. Electronic configurations. Periodic system of chemical elements. Terms.
20. Hydrogen molecule, the appearance of a chemical bond. Overlapping of atomic orbitals, covalence.

21. Energy spectrum and wave functions of an electron in an ideal crystal. Energy zones.
22. The phenomenon of radioactivity.
23. Alpha decay of nuclei. Elementary Gamow theory for alpha decay.
24. Beta decay of nuclei. Elementary Fermi theory for beta decay.
25. The binding energy of the nucleus. The Weizsacker formula for the binding energy and its justification.
26. Elementary and composite particles. Particles (mesons, baryons, quarks, leptons) are sources of fields.
27. Electron spin. The Pauli equation. Spin wave function. Spinors.

ASTRONOMY

1. Systems of spherical coordinates.
2. Phenomena of precession, nutation, aberration and refraction.
3. Measurement of time. Time scales.
4. Optical, radio and space astrometry.
5. Uneven Earth rotation around the axis. The movement of the poles. Geodynamics.
6. Star catalogues. Own movements and parallaxes.
7. Astronomical constants. Systems of astronomical constants.
8. The problem of two bodies, differential equations of motion in different frames of reference; first integrals.
9. Expansions in powers of eccentricity in the two-body problem.
10. Expansions into Fourier series in the two-body problem.
11. Calculation of ephemerides in the framework of the two-body problem.
12. Determination of the orbit in the two-body problem: by the initial conditions.
13. Determination of the orbit in the two-body problem, by boundary conditions.
14. Determination of the orbit in the two-body problem, the Gauss method based on three observations.
15. Determination of the orbit in the two-body problem: Laplace based on observations.
16. The problem of N bodies.
17. The limited three-body problem.
18. The problem of the motion of satellites.
19. Osculating elements.
20. Euler and Lagrange equations.
21. The perturbation function and its expansion.
22. The Laplace-Lagrange secular perturbation theory.
23. Improved orbits.
24. Scales of stellar magnitudes.
25. Luminosities and absolute magnitudes of stars.
26. The star colour index.
27. Temperatures of stars.
28. Classification of stellar spectra.
29. Diagram ‘spectrum-luminosity’.
30. Photometric systems.
31. Absorption of light in the Galaxy.
32. The idea of stellar evolution.
33. General structure of the Galaxy.
34. Star subsystems.
35. Star clusters and stellar associations.
36. Star formation and its triggers.
37. Starry composition of the Galaxy.
38. Luminosity functions and mass functions of the Galaxy and star clusters.

39. Stellar kinematics. Local velocity of the Sun. Rotation of the Galaxy.
40. Basic concepts of stellar dynamics.
41. Types of equilibrium of stellar systems.
42. Basic equation of stellar dynamics.
43. Jeans and Liouville theorems.
44. Integrals of the basic equation for typical cases.
45. Ergodic hypothesis.
46. The action of irregular forces in stellar systems.
47. The Jeans formula. Cumulative effect.
48. Relaxation time ('collisional').
49. Potential energy of stellar systems.
50. The virial theorem.
51. Local dynamic problem.
52. The stability condition for star clusters in the field of the Galaxy.
53. Tidal radius of cluster stability.
54. Gross-dynamic evolution of models of isolated star clusters due to star dissipation.
55. Gross-dynamic evolution of scattered star clusters in the field of the Galaxy.
56. Elements of the giant dynamics of stellar clusters that are unsteady in a regular field.
57. Invariants of the turbulent relaxation of stellar systems.
58. The most probable state of the stellar system after turbulent relaxation by D.Lynden-Bell.
59. Mechanical equilibrium of stars and its stability.
60. Radiative transfer of energy in stars.
61. Convective energy transfer in stars.
62. Nature of nuclear reactions in stars.
63. The rate of nuclear energy release in stars.
64. Laws of conservation of energy in stars.
65. White dwarfs, equation of state, Chandrasekhar limit.
66. The theory of cooling of white dwarfs.
67. The theory of the photosphere: radiation transfer, radiant equilibrium, the structure of photospheres.
68. Coefficient of continuous absorption. Absorption lines.
69. Methods for solving transfer equations.
70. Mechanisms for the formation of a continuous spectrum of stars and interstellar gas.
71. Methods for solving radiation transfer equations in the non-stationary case.
72. Ruled spectrum of atoms and molecules.
73. Formation of the observed profiles of the line spectra.
74. Methods for solving radiation transfer equations in lines.
75. Interstellar medium. Composition. The phases of the interstellar medium.
76. Distribution of gas in the Galaxy.
77. Formation of stars in molecular clouds.
78. Fragmentation of molecular clouds.
79. The role of thermal processes, turbulence and magnetic field.
80. Mechanisms of star formation.
81. Starbursts.
82. Relationship between the processes of star formation and the structure of galaxies.