**ENTRANCE EXAMINATION PROGRAM**

**FOR PHYSTECH SCHOOL OF AEROSPACE TECHNOLOGY**
**EARTH AND ENVIRONMENTAL SCIENCES**
**COMPETITIVE GROUP**

**FOR APPLICANTS ENTERING PHD PROGRAMS**

The entrance examination is conducted in the form of an interview. The interview consists of two parts:

- interview on the content of the final qualifying work written by the applicant at the end of the specialist's or master's degree - in accordance with Part I of this Program;
- interview on general theoretical questions of the chosen specialty- in accordance with Part II of this Program.

## PART I

### Questions on the final qualifying work of the applicant

(Master or specialist's degree)

1. Main provisions.
2. Novelty.
3. Relevance.

**Specialty 1.6.18.**

### Atmospheric and Climate Sciences

## PART II

### 1. General concepts of geophysics

1.1. Formation and early evolution of the Earth. Earth as a planet, the origin of the solar system, the stages of evolution of the protoplanetary disk and the formation of planets, processes in the interior of the Earth at the stage of its accumulation from planetesimals, convective processes in the growing Earth model, degassing processes and models of primary atmospheres.

1.2. Formation and evolution of the Earth's atmosphere and hydrosphere.

1.3. Electromagnetic and acoustic effects in the atmosphere during seismic processes. Electromagnetic emitters in material media. Surface electromagnetic waves. Propagation of an electromagnetic pulse in a multilayer medium.

1.4. Transfer of perturbation between different geospheres. Intergeospheric connections under strong geosphere perturbation.

### 2. Atmosphere

2.1. Structure of the atmosphere, structural features of the lower, middle and upper atmosphere. General circulation of the atmosphere.

2.2. Aeronomy of the atmosphere, solar radiation and its spectrum in different layers of the atmosphere, thermal and photochemical effects of radiation, temperature regime of the atmosphere.
2.3. Equations of Radiation Gas Dynamics. Basic methods for solving the radiation transfer equation. Air state equation. Shock waves in the atmosphere.
2.4. Wave processes of local and global scales. Propagation of sound, infrasound, acoustic-gravity waves, Rossby wave.
2.5. Experimental methods for studying the middle and upper atmosphere.

2.6. Structure, composition and main parameters of the ionosphere, photochemical and physical processes in the ionosphere: ionization by solar radiation and corpuscular fluxes, recombination processes, ambipolar diffusion.

**3. Hydrosphere**

3.1. The structure and composition of the world ocean, the composition of sea water, the vertical distribution of temperature, salinity and water density. The main layers of the oceans
3.2. Sea currents, their classification, methods of study.
3.3. The main types of waves in the hydrosphere.

**4.Magnetosphere**

4.1. Magnetic and geomagnetic field of the Earth, dipole approximation, drift of magnetic poles and its influence on the upper geospheres.
4.2. Structure and dynamics of the Earth's magnetosphere, solar wind and interplanetary magnetic field, interaction of the solar wind with the Earth's magnetosphere, electric fields and currents in the magnetosphere, electromagnetic and plasma waves in the magnetosphere, particle capture and the Earth's radiation belts.
4.3. Space weather, solar activity, magnetic storms.

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3. Michael C. Kelley. The Earth’s Ionosphere. Plasma Physics and Electrodynamics. Elsevier, 2009
4. Walter Heikkila. Earth’s Magnetosphere. Elsevier, 2012
5. S.-I. Akasofu. Exploring the Secrets of the Aurora. Springer, 2007
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12. Магницкий В.А. Внутреннее строение и физика Земли. М.: Наука, 2006.
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14. Взаимодействие в системе литосфера, гидросфера, атмосфера/ Л.Н. Рыкунов, Е.П. Анисимова, Н.К. Шелковников и др. М.: Недра, 1996.
15. Плазменная гелиогеофизика т.1 и т.2 Москва. Физматлит, 2008


**Specialty 1.6.17.**
**Oceanology**

## PART II

### 1. General information about the ocean.

1.1. The world ocean as an integral part of the geographic envelope of the Earth. The content of ocean science - oceanology; sections of oceanology; connection of oceanology with other geosciences. The main directions and prospects for the study of the ocean.

1.2. Sea water as a natural object. The molecular structure of water in a different state of aggregation; water structure models. The chemical composition of sea water.

1.3. Force fields in the ocean. Equations of motion (Euler, Lagrange, Navier-Stokes, Reynolds). Continuity equation, hydrostatics equation.

1.4. The concept of barotropism and baroclinic of the ocean.

1.5. Classification of currents in the ocean. Theories of currents (Ekman, Bjerknes, full stream, etc.) and their modern development. Influence on the development of currents, uneven distribution of wind speed and density in the oceans and seas. Main ocean current systems.

### 2. Wave motions in the ocean.

2.1. Reasons causing wave movements of waters in the oceans and seas. Classification of sea waves and mechanisms of their development. Characteristics of wave motions.

2.2. Fundamentals of the hydrodynamic theory of surface gravity and gravity-capillary waves. Dispersion, dispersion equations, phase and group velocity of waves. Short and long waves. Linear and non-linear waves. Wave energy and its flow. Wind waves: statistical and spectral methods of description. Origin and development of wind waves.

2.3. Barotropic radius of Rossby deformation. Poincaré, Sverdrup and Kelvin waves. Gradient-vortex waves, planetary and topographic Rossby waves. Waves in the tropics. Equatorial waves. Different types of coastal capture and corresponding forms of captured wave. Internal waves; theory of internal waves in a layered liquid and with continuous stratification.

### 3. Optics

3.1. Balance of light energy; its components; methods of its observation and calculation; the role of light energy in the ocean.

3.2. Hydrooptical structure, its relationship with the thermohaline structure and suspended solids in the water column. Basic hydrooptical parameters of the ocean.

3.3. Optical properties of the sea surface. Laws of propagation of light in the ocean. The influence of light waves on the development of life in the ocean.

3.4. Optical methods for studying the ocean.

### 4. Remote methods for studying the ocean and monitoring the state of its natural system

4.1. Remote methods (aircraft-helicopter, satellite). Onboard equipment, its purpose. IR radiometers, microwaves, side-looking radars, laser methods of ocean sensing.

4.2. Visual observations from aircraft. Remote measurements in the interests of oceanology, meteorology, geology, the study of the natural resources of the ocean, the protection of the natural environment of the ocean, geodesy and cartography.

4.3. Satellite support for navigation and communications. The concept of geophysical information resources.

### 5. Application of computer technology in oceanology.

5.1. Principles of construction and structure of oceanological information systems. Their optimization.

5.2. Computer atlases of the ocean.

5.3. The main directions of application of computer technology in oceanology.

5.4. The use of numerical methods in solving problems in the study of the ocean.

**References**

1. Архипкин В.С., Добролюбов С.А. Основы термодинамики морской воды. М.: Диалог — МГУ, 1998.
2. Воробьев В.Н., Смирнов Н.П. Общая океанология. Ч.2. Динамические процессы. СПб.: Изд-во РГГМУ, 1999.
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4. Гилл А. Динамика атмосферы и океана. Т. 1, 2. М.: Мир, 1986.
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12. Океанология. Физика океана. Геология океана. Химия океана. Биология океана. М.: Наука, 1977 – 1980.

## Specialty 1.6.9.
## Geophysics

## PART II

### 1. General concepts of geophysics

1.1. Formation and early evolution of the Earth. Earth as a planet, the origin of the solar system, the stages of evolution of the protoplanetary disk and the formation of planets, processes in the interior of the Earth at the stage of its accumulation from planetesimals, convective processes in the growing Earth model, degassing processes and models of primary atmospheres.

1.2. Earth's core. Composition of the inner and outer core, temperature gradient, Earth's magnetic field and energy sources in the core, paleomagnetism, geodynamo, state and evolution of the core.

1.3. Mantle and oceanic crust. Upper and lower mantle, composition, phase transformations of matter in the mantle, viscosity, lithosphere and asthenosphere, mantle thermal regime (sources and temperature), hot spots and jets.

1.4. Continental and oceanic crust. Nature of the earth's continental crust, structure and composition, evolution of the continental crust, geology and tectonics, dynamics of the continental crust. Plate tectonics hypothesis, plume tectonics. Discreteness of the earth's crust. Faults in the earth's crust.

### 2. Geomechanics

2.1. Mechanical models of a solid. Theoretical strength of a solid. Defects in crystalline bodies. Crack formation. Equilibrium Griffith crack. Dislocations. Basic mechanisms and factors of plastic deformation of rocks. Rheological models. Types of destruction: separation and shear. Limit stresses, their dependence on the type of stress state, strain rate, scale.

2.2. Strength of rocks and fracture criteria. Limit stresses, their dependence on the type of stress state, strain rate, scale. Terzaghi effective stresses. The Coulomb-Mohr criterion. Friction of rocks. Modern models of friction.

### 3. Fluid Dynamics

3.1. Filtration properties of the mountain range. The concept of "fluid", the prevalence and types of fluids, their role in tectonic processes. Characteristics of reservoir rocks: porosity, permeability. Methods and equipment for measuring the filtration properties of rocks.

3.2. Laws of motion of a viscous fluid in a porous body. Balances of mass, momentum and angular momentum. The Darcy equation and the limits of its applicability. Binary law of filtration. Filtration of two-phase fluid. Mechanics of porous media with an elastic skeleton. Piezoconductivity equation.

3.3. Formation of hydrocarbon deposits. Geophysical methods of exploration of hydrocarbon deposits. Direct and inverse problems of subsoil exploration. Hydraulic fracturing.

**4. Seismology**

4.1. Wave equation. Body and surface waves in the Earth.

4.2. Reflection and refraction of plane waves at an interface. Methods for constructing reflective boundaries. The structure of the Earth according to seismic data. seismic sources. Seismometers, methods of registration and analysis of seismic data.

4.3. Earthquakes, main characteristics. Seismic energy and seismic moment. Magnitude and intensity of an earthquake. Types of magnitudes. Magnitude saturation effect. Distribution of earthquakes over the Earth's surface and depth, correlation with the boundaries of tectonic plates and geoblocks. Man-made earthquakes.

4.4. Earthquake preparation models. Foreshocks and aftershocks. Earthquake statistics. Omori's law. Gutenberg-Richter law.

**References**


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2. Жарков в.н., Трубицын ВЛ. Физика планетных недр. М.:Наука, 1980.
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7. КочарянГ.Г., Турунтаев С.Б. Введение в геофизику месторождений углеводородов. М.: МФТИ, 2007. – 348с
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10. Николаевский В.Н. Механика нефтегазоносных горных массивов. – М.: ООО «Азбука-2000», 2007. 176 с.
11. Касахара К. Механика землетрясений. М.: Мир, 1985. 264с.


**Specialty 1.6.20.**
**Geoinformatics, Cartography**

**PART II**

**1.Subject and basic concepts of space information systems for remote sensing**

1.1. Principles of remote research. Connection of remote information with the characteristics of the studied phenomena and processes. Space and aviation systems of remote sensing (RS). Advantages of space information. Accessibility. Efficiency. Globality.

1.2. Problems of remote sensing of the atmosphere, the surface of the Earth. Earth as a single ecological system. The role of remote sensing in the study of the natural environment on a global scale and the impact of anthropogenic factors on it.

1.3. Problems of remote monitoring and exploration of objects on the Earth's surface and in the atmosphere.

1.4. Modern remote sensing systems. System approach to remote research. Spatial, spectral, radiometric and temporal resolution. Prospects for the development of space remote sensing systems.

**2. The role of the atmosphere in remote sensing of the Earth**

2.1. Characteristics of the atmosphere. Compound. Gases. Aerosols. Clouds. Fog. Haze. Transfer of radiation in a scattering and absorbing medium. Absorption of radiation by gases. Scattering by gas

molecules and aerosol particles. Rayleigh scattering. Mie Scattering. Beer-Lambert law. Optical depth. Models of the aerosol atmosphere. Meteorological visibility range.
2.2. Methods for calculating the transparency of the atmosphere. Line-by-line method. Band model methods (Elsasser model, statistical (Mayer-Goody) model). Empirical methods using the band model (aggregate method, LOWTRAN model). Two-parameter Curtis-Godson method.
2.3. Atmospheric turbulence. Diffraction of homogeneous zones. Structural function. Structural constant. Optical transfer function of a turbulent atmosphere. Random component of long and short exposures. Turbulence measurements.
2.4. Brightness (radiation) characteristics of the Earth from space. Reflected and thermal radiation. Irradiation of the Earth's surface. Direct solar radiation. Sky emission. Dependence on the height of the Sun above the horizon and observation geometry. Earth's brightness from space. Radiation from a surface area. Atmospheric contribution. Accounting for scatter radiation. Features of radiation transfer processes in the Earth's atmosphere in the infrared and microwave rang

**3.Linear filtering theory. Signals and interference in systems for receiving electromagnetic radiation.**

3.1. Deterministic signals, ways of their description. Convolution integral. Fourier transform and its functional properties. Convolution theorem and optical transfer function (OTF). Analysis of linear imaging systems using the Fourier transform. OTF of optical elements. OTF of typical elements of the information path of remote sensing systems. Central limit theorem in the analysis of linear systems. The resulting OTF.

3.2.Random signals and methods for their description. Random functions and fields. Numerical characteristics. Distribution function and probability density functions. Stationarity, homogeneity, ergodicity. Autocorrelation function and spectral density. Correlation and spectral analysis. Types of one-dimensional spectra. Transformation of spectral density by linear links. Probabilistic description of continuous images.

**4. Methods for the transmission and processing of information received by means of remote sensing.**

4.1. Image transfer methods. Characteristics of the image transmission system. Using vision models when encoding images. Encoding by pulse code modulation. Statistical coding. Predictive coding. Transform coding. Hybrid coding. Interframe coding with conditional replacement. Reducing the redundancy of binary images.
4.2. Image processing methods. Representation of images in digital form. Discretization and reconstruction of continuous images. Mathematical description of discrete images. Linear operators. Superposition operator. Two-dimensional unitary transformations. Fourier transform. Cosine transform. Sine transform. Hadamard, Haar transform. Singular transformation. Two-dimensional methods of linear processing. Processing using transform. Superposition with transformation. Convolution using fast Fourier transform. Filters based on the Fourier transform.
4.3. Basic concepts of geoinformatics. General characteristics of geographic information systems (GIS) as a class of automated IS. Spheres of GIS application. Classification of GIS by functionality and territorial coverage. Cartographic basis as a means of data integration and display. CAD technologies as a methodological basis for GIS design. The role and place of expert systems in GIS technologies. GIS tool and software. GIS and web technologies. Application of remote sensing data in GIS technologies. Technological chain of thematic processing (TP) of space remote sensing data. Methods and tools for representing raster images.
4.4. Methods for classifying remote information. Geometric, radiometric and atmospheric correction. Algorithms for expanding the dynamic range of a remote image. Application of conditional color coding of the image according to spectral channels. Principal component analysis method or Karhunen-Loève transform. Kauth-Thomas transform. Signs of multi-zone information (soil index, vegetation index, moisture index, etc.). Accounting for time characteristics, cascade classification. Morphometric analysis in geographical research. Detection of objects of a certain shape. Uncontrolled classification. Expert systems for remote sensing data.

## References


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