Federal Autonomous State Higher Education Institution
«RUSSIAN UNIVERSITY OF FRIENDSHIP OF PEOPLES NAMED AFTER PATRICE LUMUMBA»
(RUDN)

Academy of Engineering

PROGRAMME
OF THE STATE FINAL CERTIFICATION

Speciality:
01.04.02 «Applied mathematics and computer science»

Educational programme (specilisation):
Space Mission and System Design

Graduate qualification:
master

Moscow, 2024 г.

1. General terms

1.1. Responsibility and procedure for the preparation and conduct of State final tests in RUDN, as well as the list, priority and timeline required for the approval and clearance process of documents for the State final certification (SFC) between departments is determined by the procedure for the State final certification of students.

The certification is carried out by the State Attestation Commission (SAC), which consists of the examination commissions according to the list of attestation tests. The composition of the commissions is approved by the university rector. The decisions of the examination commissions and the SACs shall be taken in closed sessions by simple majority vote.

1.2 The SFC includes two types of validation tests:

1) State examination.
2) Thesis defence (TD).

1.3 The results of each type of performance test included in the IGA are determined by ratings of «excellent», «good», «satisfactory», «unsatisfactory».

2. Purposes and objectives of the State final certification

2.1. **The purpose** of the SFC is to determine whether the graduates' educational programme performance meets the requirements of the OS VO RUDN.

2.2. **Objectives of the SFC:**

- Verification of the quality of students' education in the basic natural science laws and phenomena necessary for professional activity;
- Determination of the level of theoretical and practical preparation of the graduate for the performance of professional tasks in accordance with the qualification obtained;
- Determination of the individual's desire for self-development, professional development and mastery;
- Testing the development of a sustainable motivation to work in accordance with the professional objectives of the OS VO RUDN;
- Testing the ability to identify organizational and management solutions in non-standard situations and willingness to accept responsibility for them;
- Integration of education and scientific-technical activity, enhance the effectiveness using science, technology and innovation, scientific reform and innovation promotion;
- Quality assurance of training as required according to the OS VO RUDN.

3. State examination program

3.1. **The State examination is conducted in written form and includes: the test part (computer testing by testing programs) and the main part (written form).**

3.2. **The degree to which graduates have mastered the following competences shall be verified by following means of a State examination:**

- UC-1. Able to carry out a critical analysis of problem situations based on a systematic approach, to develop an action strategy.
- UC-2. Able to manage a project at all stages of its life cycle.
- UC-2. Able to organize and manage the work of the team, developing a team strategy to achieve the goal.

- UC-4. Able to apply modern communication technologies in the state language of the Russian Federation and foreign language(s) for academic and professional interaction.
- UC-5. Able to analyze and take into account the diversity of cultures in the process of intercultural interaction.
- UC-6. Able to identify and implement the priorities of their own activities and ways to improve it based on self-assessment.
- UC-7. Able to search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data obtained from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data.
- GPC-1. Able to solve actual problems of fundamental and applied mathematics.
- GPC-2. Able to improve and implement new mathematical methods for solving applied problems.
- GPC-3. Able to develop mathematical models and analyze them when solving problems in the field of professional activity.
- GPC-4. Able to combine and adapt existing ones; information and communication technologies for solving problems in the field of professional activity, taking into account the requirements of information security.
- PC-1. Able to formulate goals, tasks of scientific research in applied mathematics and computer science, computer engineering and modern programming technologies, to choose methods and means of problem solving.
- PC-2. Able to apply modern theoretical and experimental methods to develop mathematical models of investigated objects and processes related to professional activity in the field of training and to participate in their implementation in the form of software products.
- PC-3. Able to analyse, including in English, the technical solutions worked out and applied, as well as to upgrade the technical solutions for the development of a ground-based automated spacecraft control system.
- PC-4. Able to carry out work and research on the application of mathematical methods and information technology to the ballistic design of space complexes and systems.
- PC-5. Able to participate in the development of a unified software environment, organisation and control of the software development process of information systems, automated spacecraft control system and preparation of software documentation.
- PC-6. Able to carry out work and research on the processing and analysis of scientific and technical information in the application of mathematical methods and information technology for the creation of space products and the provision of space services based on the use of remote sensing data and geographic information systems.

3.3. **Объем государственного экзамена:**

- The state examination is conducted in the form of a test generated by an electronic system by random selection of questions from the prepared test task bank, with automatic verification of the correctness of the completed tasks (computer-based test).

- The computer-based test consists of 50 questions with a multiple choice of one correct answer. The time allowed for the completion of the test is 100 minutes.

- The test is graded on the basis of 100 points. For a correct answer to a question 2 points are awarded, for an incorrect answer zero points are awarded.

3.4. **Contents of the State examination (Indicative list of subjects to be submitted to the State examination)**

- Programming (Python, C++) / Программирование (Python, C++).
- Remote Sensing and Geoinformation Systems / Дистанционное зондирование и геоинформационные системы.
- System Design / Системное проектирование.
- Aerospace Systems / Аэрокосмические системы.
- Dynamics and Control of Space Systems / Динамика и управление космическими системами.

Section 1. Mathematical analysis, advanced algebra, differential equations, complex analysis

1. Real numbers. The Lemma of Embedded Segments. The Lemma of finite cover. The Lemma of limit point. The power of the continuum. Limit of the function at point. Weierstrass's theorems on the limitation and achievability of exact faces. Fermat's, Rolls' theorems, their geometric meaning.
2. Continuity of function of one variable, properties of continuous functions.
3. Multiple variable functions, full differential. Sufficient differential conditions. Gradient.
4. Number series. Convergence of series. Convergence criterion Cauchy. Sufficient signs of convergence.
5. Absolute and conditional convergence of series. Properties of completely converging series. Series multiplication.
6. Power Series; Taylor Series; Sufficient Taylor Series Condition.
7. Riemann integral as base limit. Necessary integration condition. Classes of integrable functions. Riemann integral properties. First Medium Theorem.
8. Gauss-Ostrogradsky and Stokes formulas.
9. Linear spaces, their subspace. Basis. Dimension. Matrix rank theorem. System of linear equations. Kronecker-Capelli theorem.
10. Linear mapping, matrix operations, solving systems of linear algebraic equations by Gaussian method. Implicit function theorem.
11. Euclidean space. Orthonormal bases. Orthogonal matrices. Symmetric transformations. Bringing Quadratic Form to Main Axes.
12. First order differential equations. Solution existence and uniqueness theorem.
13. Linear differential equation of second order. Linear uniform equation. Linear dependence of functions. Fundamental solutions system. Vronsky determinant. Linear non-homogeneous equation.
14. Linear differential equation with constant coefficients.
15. Complex numbers, Muavr formula. Complex variable functions, their derivatives. Cauchy-Riemann conditions.

Section 2. Programming technologies and algorithmization

1. General data types of Python. Dynamic typing and its features. Explicit type specification and

type transformation.

2. Mathematical operators and their application to basic data types. Number operations. String operations. Logical operations. (Assignment, addition (and concatenation), division with and without remainder, remainder from division, etc.). Conditional operators (if-else) and cycles (for, while): syntax, usage features, compact record form. Continue and break operators. The range() function.
3. Standard data structures (lists, tuples, sets, dictionaries, numpy arrays) and features: creating, deleting, accessing, modifying and adding elements.
4. Classification and «levels» of programming languages. Concept of machine-oriented language. Major differences between Python and C programming languages.
5. Block Software Unit for C/C++ languages, syntactic rules for selecting blocks and their types.
6. Memory model in C/C++: time of life, visual range, binding.
7. Storage classes defined by keywords: auto, register, static, extern. Using the words static and extern to define the lifetime and range of the variable.
8. Basic data types of C/C++. Variable memory representation. Variable overflow.
9. Syntax structures providing branches (if-else, ternal operator, goto, switch) and repetitions (while, for, goto).
10. Arithmetic and logical operators. Unari and binary operators.
11. Bitwise operators
12. Binary operator «,» (comma) and combining expressions.
13. Directories and addresses. Location of variables in memory. Directories and arrays (location of array elements in memory). Address arithmetic. Access to array elements by index and pointer. Void pointer. Void pointer features.
14. Static and dynamic memory.
15. Concept of function and practice of its application. Embedded and user functions. Function-methods. Overhead costs for calling function.
16. User functions: function design, input and output parameters, default options and key mapping. Variable number of parameters in function. Declaring and calling user function.
17. Program Error Interception and Handling: Operating Principle, Syntax, Examples.
18. Concept of recursion. Basic elements of recursive function. Caching at recursion.
19. Structured data types: arrays, character strings, structures, associations, enumeratable data type, bit fields. Syntax features of the announcement, initialization and work. Features of «packaging» in memory. Examples of use.
20. Dynamic Data Structures: Vector, Queue (stack), List as Examples of Dynamic Organization of Structured Data.
21. Text and binary files and their data storage feature. Direct access files.
22. The concept of an algorithm. Algorithm property. The notion of an enforcer. Example of an enforcer: a Turing machine. Computability, computable and incomparable functions.
23. The concept of complexity. Complexity types. Complexity assessment: polynomial and non-plinominal algorithms. Comparing the complexity of an algorithm with an example of a power-to-number problem.
24. Integer Programming Problems. NP-complete Problems. Backpack Problem. Traveler Problem
25. Greedy algorithms. Example: backpack problem.
26. Strategy «divide and conquer», connection with recursion.
27. Sorting algorithms and their complexity: sorting by choice, sorting by inserts, bubble method, sorting by merge, quick sorting.
28. Search Algorithms: Sequential Search, Area Constriction Methods.
29. The notion of graph. Simple, directed, weighted graph. Representation of the graph in computer memory. Algorithms on graphs: deep traversal, breadth traversal. This is possible. Shortest path restoration.
30. The concept of algorithmic dynamic programming. Similarity and difference with strategy «divide and rule» (example: calculation of Fibonacci numbers). Concept of bottom-up solution. Example: ATM problem.

31. Basic principles of programming (procedural programming, object-oriented programming, functional programming).
32. Basic principles of object-oriented programming: encapsulation, inheritance, polymorphism.
33. Parallel programming. Motives and assumptions of parallelism. Laws (principles) of Moore, Dennard, Amdala, Gustafson.

Section 3. Theoretical mechanics, mechanics of launch vehicle and spacecraft flight

1. Kinematics of a point. Theorems on the addition of velocities and accelerations.
2. Planar parallel motion of a solid body. Centre of velocities. Centroids. Euler's formula for the distribution of velocities in solids. Rivals formula for distribution of accelerations in solids.
3. Spherical motion of a solid. Angular velocity addition theorem. Axoids. Euler angles.
4. Dynamics of a point. Newton's laws. The principle of determinacy.
5. Dynamics of relative motion of a point. Weight of a body on a rotating Earth.
6. First integrals of equations of motion. The phase plane. The phase portrait of a mathematical pendulum.
7. Kepler's laws. Kepler's problem. The first integrals of Kepler's problem.
8. Moment of inertia. Tensor of inertia. Centre of mass. Huygens-Steiner theorem.
9. General theorems of dynamics for a system of free material points. First integrals.
10. Definition of relations imposed on a system. Examples of holonomous and nonholonomous, stationary and non-stationary relations. Generalised coordinates.
11. Second kind Lagrange equations. Generalized forces. The Lagrange function.
12. First integrals of Lagrange equations of the second kind.
13. Linearisation of second kind Lagrangian equations near a stable equilibrium position. 47.
14. Hamilton equations. First integrals.
15. Canonical transformations. The Hamilton-Jacobi equation.

Раздел 4. Dynamics and Control of Space Systems

1. The 2-body problem. The four components of the bounded 2-body problem.
2. Sphere of attraction. Sphere of planetary action. Sphere of planetary influence.
3. Coordinate systems used in the study of spacecraft motion.
4. Radial, transversal component of spacecraft velocity. The sectorial velocity of a spacecraft.
5. The orbit equation. Apsis line, pericenter, apocenter, true anomaly angle, focal parameter, eccentricity, semi-major axis. First space velocity, parabolic velocity, hyperbolic velocity.
6. Keplerian elements of unperturbed motion. Line of knots, knots of orbit, longitude of ascending knot, angular distance of pericenter or argument of pericenter, inclination of orbit, argument of latitude.
7. Motion of a spacecraft in an elliptical orbit. True, eccentric, and mean anomalies. Movement of spacecraft in a circular orbit, parabolic orbit, hyperbolic orbit.
8. Disturbed motion of spacecraft. General characteristics of perturbations. External causes in relation to the spacecraft, variation of initial data, internal processes in the spacecraft. The secular and periodic perturbations.
9. The method of osculating elements. The moment of osculation, osculating orbit, osculating plane, osculating elements. Newton-Euler equation. Advantages of the method. The "secular" terms.
10. Aerodynamic influence on the spacecraft. Main aerodynamic factor. Atmospheric density. Atmospheric disturbances. Time of spacecraft existence in orbit. Critical orbit.
11. Models of the Earth's gravitational field. Central Newtonian field. Effects of noncentral gravity field. Effects of perturbations caused by accounting for the compression of the Earth. Perturbations caused by the attraction of the Sun and the Moon.
12. Period of rotation. Draconic, sideric, anomalous, osculating, unperturbed periods of circulation.
13. The maneuvering task. Types of maneuvers according to their functional purpose.
14. Criteria for maneuver optimality. Ideal and characteristic speed of a maneuver.
15. Action of tangential and normal control forces. Their influence on orbit parameters.

16. Lagrange problem as the problem of destroying an asteroid provided that the final energy costs of the rocket flight are minimal
17. Autonomous Flight Control of Spacecraft
18. Spacecraft Aerodynamic Control at Planet Landing
19. Optimization of the shape of the spaceship in Newton's aerodynamic problem
20. Flight trajectories determined by a system of differential equations with singular points.

Section 5. Remote Sensing and Geoinformation Systems

1. Give examples of the use of different sets of spatial data in specific industries.
2. Justify their importance for solving the problems facing the relevant industry.
3. Tell about the applied methods of complex analysis of spatial data and their features when solving specific industry problems.
4. Tell about the features of geo-information support of data in geoportals.
5. Give examples successful regional and sectoral geoportals. Name their strengths and weaknesses, taking into account the industry specifics of the tasks solved by these geoportals.
6. List the capabilities of the technology platforms selected for deploying these geoportals (taking into account their technical limitations).
7. List the main stages of pre-processing of satellite imagery.
8. List the combinations of spectral zones, the most informative for the selection of industrial objects, give examples of options for color synthesis of images.
9. Tell about the features of recognition and classification in the image of homogeneous objects using the values of spectral brightness.
10. Define and review the history of remote sensing and the evolution of remote sensing and remote sensing systems. Electromagnetic radiation (EMR), terms and definitions, laws of radiation, EM spectrum, sources of EMR.
11. Active and passive systems, mapping and other systems, the concept of resolution in remote sensing - spatial, spectral, radiometric and temporal. Orbits and platforms for observing the Earth.
12. Reception, processing and creation of information products. Mastering the freely distributed MultiSpec program for the analysis of multispectral Landsat data (on the example of various objects and industries).
13. Remote Sensing Applications in Earth, Ocean, Atmospheric, Emergency and Climate Change Sciences.
14. The use of GIS for the analysis of remote sensing data
15. Digital elevation model; air pollution.
16. The use of geographic information systems based on remote sensing data in the interests of various industries.
17. Methods for complex analysis of spatial data and their features when solving specific industry problems;
18. Geoportal solutions based on the use of design documentation in industry management.
19. Possibilities of technological platforms selected for the deployment of geoportals data
20. Web GIS, EO data warehouses, near real-time access to EO data and processing in cloud storage.
21. Cloud data warehouse, web platform for remote data processing EO, SaaS, DaaS GIS-as-a-Service, Data Cube, Analysis Ready Data.

Examples of the test questions:

The spectral region of the electromagnetic radiation which passes through the atmosphere without much attenuation is known as:

ozone hole

atmospheric window

ozone window

The remote sensing techniques applied for the earth's surface features, is generally confined to the following wave lengths:

0.4 to 1.3, 1.5 to 1.8, 2.2 to 2.6 μm

4.2 to 5.0, 7.0 to 15.0 μm and 1 cm to 30 cm

All of these

Which one of the following parameters is accurate for DGPS:

Positional accuracies ~ 1 - 2 m if rover is less than 1-2 km from the reference station

Positional accuracies ~ 2 - 5m if rover is less than 2-5 fm from the reference station

Positional accuracies ~ 5 - 10 m if rover is less than 5-10 km from reference station

The most widely used antenna in GPS is:

Paraboloid antenna

Microstrip antenna

Horn antenna

The reflection of solar energy is characterised by the water content in the leaf, in the reflective optical infrared:

visible (0.4 - 0.7 μm) region

near-IR (0.7 - 1.3 μm) region

short wave-IR (1.3 - 2.7 μm) region

Orbital radius of GPS satellites is approximately:

15,200 km

26,600 km

18,400 km

For interpolation of satellite data used for monitoring dynamic changes that occure on the earth surface, the most suitable orbit for the satellite is:

circular orbit

sun-synchronous orbit

near polar orbit

The altitudinal distance of a geostationary satellite from the earth is about:

26, 000 km

30, 000 km

36, 000 km

The infrared portion of EMR lies between

0.4 - 0.7 μm

0.7 - 1.3 μm

0.7 to 14 μm

For C band Synthetic Aperture Radar (SAR) with Doppler band width of 1300 Hz, the coherence length lcoh is:

130 km

230 km

250 km

In sun light, water rich in phytoplankton appears:

red

green

brown

The main functional blocks of a multispectral scanner (MSS) are given below:

Video processor

Dispersive system

Detector

Which of the following is INCORRECT when describing the geometry of side-looking radar (SLR)?

SLR geometry makes radar imagery an excellent choice for applications such as forestry and land-use mapping

SLR geometry makes radar quite useful for terrain analysis

SLR geometry can result in several image effects such as foreshortening, layover, and shadow

Which of the following is an INCORRECT description of the interaction between sunlight, the atmosphere and the earth's surface?

30% of the Sun's energy is reflected back into space

50 % of the Sun's energy is absorbed by the Earth's surface

10% of the Sun's energy is absorbed by the Earth's vegetation

The refractive index of the ocean water:

increases with salinity

increases with temperature

decreases with temperature

The spatial resolution of most of the bands of the Landsat OLI sensor is _____ not including the panchromatic and thermal infrared bands

About 15 meters

About 30 meters

About 80 meters

There is an artificially generated colour image in which blue, green and red colours are assigned to the wavelength regions to which they do not belong in nature. It is called:

Sensor

Colour Composite

Spectral Band

Choose the correct statement from the following:

Phytoplankton contains photosynthetically active pigment

An increase of phytoplankton decreases the back scattering in the green region

An increase of phytoplankton increases the back scattering in the green region

The following are members of the "critical six" GIS functional capabilities EXCEPT:

Data capture

Data Analysis

Networking

A buffer operation performed on a point selects an area shaped like a:

Rectangle

Triangle

Circle

Typical data input or data capture functional capabilities for GIS DO NOT include:

Digitizing

Mosaicking

File compression

Which of the following is not an example of spatial data?

Times of urban events

Lines showing the route of linear objects

Points showing location of discrete objects

4.Methodological recommendations for the preparation and passing of the State examination

4.1. **Recommended literature:**

1) Bolotin S.V., Karapetyan A.V., Kugushev E.I., Treschev D.V. Theoretical Mechanics. Textbook. - Moscow: Academia Publishing Center, 2010. - 432 c. ISBN 978-5-7695-5946-4

2) Demin V.G. The motion of an artificial satellite in a non-central gravitational field. Moscow-Izhevsk. 2010. - 420 c. ISBN 978-5-93972-851-5

3) Arnold V.I., Kozlov V.V., Neishtadt A.I. Mathematical aspects of classical and celestial mechanics. "Modern problems of mathematics. Fundamental Directions. VOL.3" MOSCOW, 1985. - 304 p.

4) Baranov A.A., Razumny V.Yu. Formation and Maintenance of Spacecraft Orbits with Low thrust engines. - Preprint of the Keldysh Institute of Applied Mathematics. Preprint of the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences, 2010. - № 52. - 32 p.

5) Okhotsimsky D.E., Sikharulidze Y.G. Fundamentals of Space Flight Mechanics. Textbook. - Moscow: Nauka, 1990. - 448 p.

6) Lawden D.F. Optimal trajectories for space navigation. - Moscow: Mir, 1966. - 152 p.

7) Chernov A.A., Chernyavsky G.M. Orbits of Remote Sensing Satellites: Lectures and Exercises. - Moscow: Radio and Communications, 2004. - 200 p.

8) Alexeev K.B., Bebenin G.G., Yaroshevsky V.A. Spacecraft Maneuvering. - Moscow: Mashinostroenie, 1970. - 232 p.

9) Eliasberg P.E. Introduction to the Theory of Flight of Artificial Earth Satellites. - Moscow: Nauka, 1965. - 540 p.

10) Sikharulidze Y.G. Ballistics of Flying Vehicles. - Moscow: Nauka, Main Editorial Office for Physical and Mathematical Literature, 1982. - 352 p.

11) Reshetnev M.F., Lebedev A.A., Bartenev V.A., Krasilshchikov M.N., Malyshev V.A. Control and Navigation of Artificial Earth Satellites in Circular Orbits. - Moscow: Mashinostroenie Publisher, 1988. 336 p.

12) Solovyov Ts.V., Tarasov E.V. Forecasting interplanetary flights. - Moscow: Mashinostroenie, 1973. - 400 p.

13) Sehgal, J. (1996). Pedology : Concepts and Applications , Kalyani Publishers, New Delhi.

14) Remote Sensing applications in Agriculture by JA Clarke and MD Steven

15) Applications of Remote Sensing to agrometeorology (Ed. F. Toselli), Kluwer Academic Publishers.

16) Kustas, WP and Norman, JM (1996). Use of remote sensing for evapotranspiration monitoring over land surfaces. Hydrological sciences Journal, 41(4): 495-515.

17) F.A.O. (1991). Land Use Planning applications: World Soil Resources Reports; 68. Rome, FAO, 206 p.

18) Sabine Grunwald (2006). Environmental Soil –Land Scape Modeling; Geographic Information System and Pedomatrics, Taylor & Francis Group, LLC.

19) Satellite Remote Sensing and GIS Applications in Agricultural Meteorology (2005). Edited by Sivakumar et al , CaMG, WMO, Geneva.

20) Curtis H. Orbital mechanics for engineering students. – Elsevier, 2013 – 912 p.

21) Martin Wegmann, Jakob Schwalb-Willmann, Stefan Dech An Introduction to Spatial Data Analysis: Remote Sensing and GIS with Open Source Software (Data in the Wild) 1st Edition, Kindle Pelagic Publishing, 2020

22) E.O. Wilson, Dawn J. Wright, Christian Harder GIS for Science, Volume 3: Maps for Saving the Planet. Esri Press, 2021, 228p

23) Tom Koch Cartographies of Disease: Maps, Mapping, and Medicine, new expanded edition Esri Press, 2017, 412p

24) Jindong Li Satellite Remote Sensing Technologies Springer, Singapore, Space Science and Technologies, 2021, 421p

25) Remote Sensing and Image Interpretation, 7th Edition, Thomas Lillesand, Ralph W. Kiefer, Jonathan Chipman, 736 p

26) List of available Indices Index DataBase A database for remote sensing indices. URL: https://www.indexdatabase.de/db/i.php

27) Classical and Modern Methods of Automatic Control Theory. Textbook in 5 vols. 2nd edition, revised and supplemented / Edited by K.A. Pupkov, N.D. Egupov. - Moscow: Bauman Moscow State Technical University Publisher, 2004.

28) Pupkov K.A. Modeling and Testing of Automatic Control Systems. Tutorial. - M.: RUDN, 2014. – 98p.

29) Duboshin G.N. Celestial mechanics. Basic tasks and methods. - M.: 2011. 849 p. Pontryagin L.C. Ordinary differential equations.

30) Kosarev V.I. 12 lectures on computational mathematics (introductory course). - M.: Ficzmatbook, 2013 – 240p.

31) Bakhvalov N. S., Liquid N.P., Kobelkov G.M. Numerical methods. - M.: Science, 1987.

32) Python 3. Essential. Prochorenok H., Drones B., BHB-Petersburg, 2019 – 610p;

33) Python. Express Course. Seder H., SPb.: Peter, 2019 - 480 p.;

34) Algorithms. Handbook with examples on C, C++, Java and Python. Heineman J., Pollis G., Selkov S., SPb.: "Alpha Book", 2017 - 432 p.;

35) Automating Injured Tasks with Python: Practical Guide for Beginners. Sveirart Al., M.:"ID Williams", 2017 - 592 p.;

36) Numerical methods: Computational workshop. Vabišević P.N., M.: «LIBROCOM», 2010 - 320 p;

37) High-level programming. C/C++. Habibullin I.S., SPb.: BHB-Petersburg, 2006 - 512 p;

38) C++ programming in Visual Studio 2010 Express. Prochorenok N.A., 2010 - 71 p.;

39) C++. Straustrup B., Martynov N.N., Moscow: Binom, 2011. - 1135 p.;

40) Programming and Computer Science. Antonyuk V.A., Ivanov A.P., Moscow: Physical Fick. MGU M. V. Lomonosova, 2015 - 64 p.

41) Artificial intelligence with examples in Python Joshi P., M., SPB.:Dialectics, 2019 - 450 p.

42) Algorithms. Construction and analysis. Korman T. et al. Williams Publishing House, 2009 - 1296 p.

43) Algorithms. Introduction to development and analysis. A.V. Levitin, Williams, 2006. - 574 p.

44) Algorithms. Dasgupta C., Papadimitriou X., Vazirani U., ICNMO, 2014 - 320 p.

4.2 **Additional recommendations**

In preparing for the State examination, the student is advised to recall the basic functions and assignment of specialized software after completing several study assignments.

The test part of the State examination is performed on a computer in a specialized testing programme (Mentor, TUIS or other testing programme) without the use of notes, textbooks or other reference literature, and without the use of electronic equipment (except for the computer on which the test is performed).

The main part of the State examination takes place in writing, without the use of notes, textbooks or other reference literature, and without the use of electronic equipment.

1. **Means of assessment**, designed to meet the requirements of a VO RUDN/FGOS VO-compliant graduate's level of training

Grade «5» (Excellent, 86-100 points) is given if:

The contents of the examination certificate are fully disclosed;
– The material is written in a logical sequence;
– Systematic and in-depth knowledge of the programme material demonstrated;
– Terminology is used precisely;
– The ability to illustrate theoretical provisions with concrete examples and to apply them to a new situation;
– The assimilation of previously studied related issues, the formation and sustainability of competences, skills and abilities have been demonstrated;
- The answer was given on its own, without leading questions;
– Demonstrated ability to apply theory creatively to professional tasks;
– Knowledge of modern educational and scientific literature has been demonstrated;
– There are one or two inaccuracies in the treatment of minor matters that are corrected by the comment.

Grade «4» (good, 69-85 points) is given if:
– The examination material is presented in a systematic and consistent manner;
– Demonstrated ability to analyse material, but not all conclusions are reasoned and evidentiary;
– the assimilation of basic literature is demonstrated.
– The answer meets mainly the requirements of the rating of the «5», but has one of the disadvantages:
– There were minor lacunae in the presentation which did not distort the content of the reply;
– One or two shortcomings in the coverage of the main content of the answer, corrected by the examination;
– There was an error or more than two deficiencies in the illumination of secondary questions, which are easily corrected by the examining magistrate's observation.

Grade «3» (satisfactory, 51-68 points) are given if:
– The content of the material is not fully or consistently explained, but a general understanding of the matter is shown and sufficient skills are demonstrated for further assimilation of the material;
– Major categories have been absorbed for the issues considered and additional;
– There were difficulties or errors in the definition of concepts, in the use of terminology, corrected after several leading questions;
– In the case of incomplete knowledge of theoretical material, a lack of formation of competencies, abilities and skills has been identified, and the student cannot apply the theory in the new situation;
– the assimilation of basic literature is demonstrated.

Grade «2» (unsatisfactory, 0-50 points) is given if:

– The basic content of the teaching material is not disclosed;
– Knowledge or lack of understanding of more or the most important part of the teaching material;

– There have been errors in the definition of concepts, in the use of terminology, which have not been corrected after several leading questions;
– Competence, skills and skills have not been developed.

2. Requirements for final qualification work

Graduates who have passed a State examination are eligible for the protection of the FQW.

The FQW shall be defended at a public meeting of the SAC in the form of an oral presentation of the FQW followed by oral answers to questions from SAC members. The report and/or answers to the questions of the SAC members may be in a foreign language.

The protection of the FQW verifies the degree to which graduates have acquired the following competencies:

- UC-1. Able to carry out a critical analysis of problem situations based on a systematic approach, to develop an action strategy.
- UC-2. Able to manage a project at all stages of its life cycle.
- UC-2. Able to organize and manage the work of the team, developing a team strategy to achieve the goal.
- UC-4. Able to apply modern communication technologies in the state language of the Russian Federation and foreign language(s) for academic and professional interaction.
- UC-5. Able to analyze and take into account the diversity of cultures in the process of intercultural interaction.
- UC-6. Able to identify and implement the priorities of their own activities and ways to improve it based on self-assessment.
- UC-7. Able to search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data obtained from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data.
- GPC-1. Able to solve actual problems of fundamental and applied mathematics.
- GPC-2. Able to improve and implement new mathematical methods for solving applied problems.
- GPC-3. Able to develop mathematical models and analyze them when solving problems in the field of professional activity.
- GPC-4. Able to combine and adapt existing ones; information and communication technologies for solving problems in the field of professional activity, taking into account the requirements of information security.

- PC-1. Able to formulate goals, tasks of scientific research in applied mathematics and computer science, computer engineering and modern programming technologies, to choose methods and means of problem solving.

- PC-2. Able to apply modern theoretical and experimental methods to develop mathematical models of investigated objects and processes related to professional activity in the field of training and to participate in their implementation in the form of software products.

- PC-3. Able to analyse, including in English, the technical solutions worked out and applied, as well as to upgrade the technical solutions for the development of a ground-based automated spacecraft control system.

- PC-4. Able to carry out work and research on the application of mathematical methods and information technology to the ballistic design of space complexes and systems.

- PC-5. Able to participate in the development of a unified software environment, organisation and control of the software development process of information systems, automated spacecraft control system and preparation of software documentation.

- PC-6. Able to carry out work and research on the processing and analysis of scientific and technical information in the application of mathematical methods and information technology for the creation of space products and the provision of space services based on the use of remote sensing data and geographic information systems.

a. Illustrative list of topics of FQW:

1. Study of generative-adversarial recurrence neural networks to detect anomalies in multidimensional time series.
2. Intellectualization of geo-information databases in the exploitation of natural resources of the Democratic Republic of the Congo
3. Calculating economic risks by machine learning
4. Use of artificial intelligence algorithms to assess borrowers' creditworthiness
5. Development of a methodology to solve transport logistics problems using a genetic algorithm
6. Web Camera Augmented Reality Generation Software Development
7. Development of a software complex to visualize routing algorithms using augmented reality and geolocation technology
8. Application of Cryptographic Techniques to Secure Cloud Services
9. Development and Research of a Synthetic Control Method for Mobile Robots
10. Neural Network Dynamic Object Control
11. Development of an autonomous first-stage launch vehicle landing control based on video flow analysis

6.5 **Assessment tools of FQW:**

The theme of FQW should be relevant and relevant to the current state and prospects of science and technology. The theme of the FQW could include the use of research results from the Department of Mechanics and Mechatronics of the Space Research Institute and their development, possibly proposed by the heads of enterprises (institutions, organizations)This is confirmed by a written application addressed to the Rector or or the First Vice-Chancellor of the University, recommending the selection of the topic of the FQW of interest to the enterprise. The teaching themes of the FQW are allowed for the preparation and conduct of the teaching process. Topics may be

proposed for the development of a comprehensive FQW by a group of students, each of whom develops in detail a particular topic of common interest.

Students are given the right to choose a topic for FQW, including the right to propose a topic justifying its development.

It is recommended that the theme of the FQW be chosen well in advance so that the course papers (drafts) and the practice programme, when reading the literature, can accumulate material for in-depth and thorough work on the topic. In this case, the preliminary fixation of the FQW topic is made in the form of a student's statement, which is approved at a meeting of the department (institute).

The subject of the FQW is assigned to the student in the form of an assignment for the performance of the HCR. The student is assigned by the head of the FQW. This assignment is completed in two copies, one of which is with the student and the other with the university.

The time frame for the implementation of the FQW is determined by the curriculum of the training area and is specified in the FQW assignment. The completion of the FQW should be scheduled no later than 10 days before the commencement of SAC.

The results of the protection of the FQW are determined on the basis of assessments:

– The scientific supervisor for the quality of the work, the degree to which it meets the requirements of an appropriate level of FQW;

– Reviewer for the work as a whole, taking into account the soundness of the conclusions and recommendations, their novelty and their practical significance;

– members of the LEG for the content of the work, its protection, including the report, responses to the comments of the reviewer.

Criteria for assessing FQW

№ п/п	Assessed components of FQW	Criteria	Feature
.	**Problem articulation and validity**	▪ Relevance of the topic of work and the research issue ▪ Theoretical and/or practical relevance of the study ▪ The correctness of the goals and objectives of the study and their relevance to the topic	▪ Report ▪ Sections of the text containing the substitution and description of the task (introduction, literature review, theoretical part, etc.) ▪ Reviews by Scientific Director and Reviewer ▪ Answers to questions
.	**Literature review**	▪ Scientific and theoretical level, completeness and depth of theoretical research ▪ Number of sources used, e.g. in foreign languages ▪ Relevance of used sources ▪ Quality of critical analysis of publications, their relevance	▪ Report ▪ Sections of the text describing the problem, setting the problem, placing the study in the relevant literature on the topic (introduction, literature review, theoretical part) ▪ Reviews by Scientific Director and Reviewer ▪ Answers to questions
.	**Collection, analysis and systematization of data and information**	▪ Autonomy and quality of the results of information analysis (data/information collection, analysis and systematization); ▪ Reliability of the information sources used; ▪ Completeness of data provided to achieve the objectives (coverage of the external and internal environment);	▪ Report ▪ Sections of the text describing the data and information used for the study and justifying the methods and solutions used for the collection and analysis of data and information (literature review, theory, practice, methodology) ▪ Reviews by Scientific Director and Reviewer

			▪ Answers to questions
.	**Study**	▪ Independence and quality of empirical research; ▪ Autonomy of choice and validity of the models/methods of quantitative and qualitative analysis. ▪ Correctness of analysis, estimation/computation methods in empirical research	▪ Report ▪ Sections of the text containing the practical part of the study, conclusions and comments (introduction, practical part, conclusion) ▪ Peer reviews ▪ Disclaimer's recall ▪ Answers to questions
.	**General conclusion on the work**	▪ Reliability, novelty and practical relevance of the results; ▪ Autonomy, validity and consistency of conclusions; ▪ Full implementation of the tasks assigned; ▪ The autonomy and depth of the overall study; ▪ Literacy and consistency in writing.	▪ Report ▪ Sections of the text containing conclusions and comments (introduction, practice, conclusion) ▪ Reviews by Scientific Director and Reviewer ▪ Answers to questions
.	**Report and presentation**	▪ Clarity, logic and professionalism of the report; ▪ Presentation presentation visibility and structure; ▪ the ability to use professional vocabulary and conceptual-categorical apparatus correctly.	▪ Report ▪ Reviews by Scientific Director ▪ Answers to questions
.	**Responses to questions**	▪ Degree of knowledge of the topic; ▪ Clarity and science of the author's arguments; ▪ clarity of answers.	▪ Responses to reviewers' comments ▪ Responses to questions raised by members of the commission

7. Normative documents

«Regulation of state final certification...» approved by order of Rector 768 of 14.12.2015 (http://quality.rudn.ru/file.php?id=340).
«Order of the final state certification...» approved by order of Rector 790 of 13.10.2016 (http://quality.rudn.ru/file.php?id=339).
«Rules of preparation and completion of final qualification work...» approved by Rector Order 878 of 30.11.2016 (http://quality.rudn.ru/file.php?id=338).
«The Regulation on the Inspection of Written Works of Learners in the system «Antiplagiate.RUDN», approved by Rector Order 228 of 30.03.2018 (http://quality.rudn.ru/admin_site/file.php?id=451).

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