Federal State Autonomous Educational Institution of Higher Education
"Peoples' Friendship University of Russia named after Patrice Lumumba"

Academy of Engineering
(name of the main educational unit (MEU) that developed the educational program of higher education)

WORKING PROGRAM OF THE DISCIPLINE

MATHEMATICS FOR SPATIAL SCIENCES
(name of discipline/module)

Recommended for the field of study/specialty:

27.04.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the training area/specialty)

The discipline is mastered within the framework of the implementation of the main professional educational program of higher education (EP HE):

AIML and Space Sciences / Artificial Intelligence, Machine Learning and Space Sciences
(name (profile/specialization) of the educational institution of higher education)

2025

1. THE GOAL OF MASTERING THE DISCIPLINE

The discipline "Mathematics for Spatial Sciences" is part of the master's program "Artificial Intelligence, Machine Learning and Space Sciences" in the direction 27.04.04 "Control in Technical Systems" and is studied in the 1st semester of the 1st year. The discipline is implemented by the Department of the Partner University. The discipline consists of 9 sections and 19 topics and is aimed at studying the methods of mathematical processing and analysis of spatial data.

The purpose of mastering the discipline is - the formation of a comprehensive knowledge reflecting the modern level of methods of mathematical processing and analysis of spatial data; - an expanded understanding of fundamental and modern algorithms for processing and analysis of spatial data; - the study of additional sections of matrix algebra and mathematical statistics underlying the analysis of data obtained from various sources; - the study of synthesized algorithms for optimizing the results of geodetic measurements using the least squares method.

2. REQUIREMENTS TO THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline " Mathematics for Spatial Sciences " is aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies developed in students while mastering the discipline (results of mastering the discipline)

Cipher	**Competence**	**Indicators of Competence Achievement** (within the framework of this discipline)
GPC-1	Able to analyze and identify the natural scientific essence of control problems in technical systems based on provisions, laws and methods in the field of natural sciences and mathematics	GPC-1.1 Knows the basic laws, provisions and methods in the field of natural sciences and mathematics; GPC-1.2 Able to identify the natural scientific essence of control problems in technical systems, guided by the laws and methods of natural sciences and mathematics; GPC-1.3 Has knowledge of tools for analyzing control problems in technical systems;
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them	GPC-2.1 Knows the basic methods of solving control problems in technical systems; GPC-2.2 Able to justify methods for solving control problems in technical systems; GPC-2.3 Proficient in methods of setting control tasks in technical systems;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	PC-2.1 Knows modern theoretical and experimental methods used to develop mathematical models of the objects under study and processes of professional activity; PC-2.2 Able to determine the effectiveness of the methods used to develop mathematical models of the objects and processes under study; PC-2.3 Has mastered modern theoretical and experimental methods for developing mathematical models of objects and processes of professional activity in the field of study;

3. PLACE OF THE DISCIPLINE IN THE STRUCTURE OF THE EDUCATIONAL EDUCATIONAL EDUCATION

Discipline " Mathematics for Spatial Sciences" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Mathematics for Spatial Sciences ".

Table 3.1. List of components of the educational program of higher education that contribute to the achievement of the planned results of mastering the discipline

Cipher	Name of competence	Previous courses/modules, practices*	Subsequent disciplines/modules, practices*
GPC-1	Able to analyze and identify the natural scientific essence of control problems in technical systems based on provisions, laws and methods in the field of natural sciences and mathematics		Undergraduate practice / Pre-graduation practice; Geoinformation Systems and Applications;
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them		Undergraduate practice / Pre-graduation practice;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management		Research work / Research work (acquiring primary skills in research work); Undergraduate practice / Pre-graduation practice; Research Work; Dynamics and Control of Space Systems; *Artificial Neural Networks (Deep Learning)***; *Artificial Neural Networks (Deep Learning)***; Advanced Methods of Space Flight Mechanics; *Artificial Neural Networks (Reinforcement Learning)***; Operations Research and Optimization Techniques;

* - filled in in accordance with the competency matrix and the SUP EP HE

** - elective disciplines/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF STUDY WORK

The total workload of the discipline "Mathematics for Spatial Sciences" is "7" credit units.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,**ac.h.		**Semester(s)**
			1
Contact work, academic hours	*68*		*68*
Lectures (LC)	34		34
Laboratory work (LW)	0		0
Practical/seminar classes (SC)	34		34
Independent work of students, academic hours	*157*		*157*
Control (exam/test with assessment), academic hours	*27*		*27*
General complexity of the discipline	**ac.h.**	***252***	*252*
	credit.ed.	*7*	*7*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Contents of the discipline (module) by types of academic work

Section number	Name of the discipline section	Section Contents (Topics)		Type of academic work*
Section 1	Introduction. General Provisions. Objectives and tasks, areas of application of geostatistical analysis.	1.1	Basic concepts of geostatistics: random variable, spatial variable, random function.	LC, SC
		1.2	Moments of spatial functions in linear geostatistics: mathematical expectation, dispersion, covariance, variogram. Ergodicity property of random functions.	LC, SC
		1.3	Conditions necessary for the application of geostatistical methods	LC, SC
Section 2	Review of fundamental methods of mathematical processing of measurement results	2.1	Ordinary least squares (OLS) spatial data optimization algorithms.	LC, SC
		2.2	The main stages of algorithm implementation, assessment of the accuracy of the initial and optimized values of spatial data.	LC, SC
Section 3	Block matrices	3.1	Definition of block matrices.	LC, SC
		3.2	Operations with block matrices: addition, transposition, multiplication, inversion. Solution of systems of linear algebraic equations (SLAE) in block notation.	LC, SC
Section 4	Mathematical processing and analysis of correlated paired data.	4.1	Using block matrices to construct algorithms for correlated and parametric versions of least squares optimization of paired data.	LC, SC
		4.2	Analysis of paired data for the presence of rough measurements and testing the hypothesis of insignificance of the mean differences of paired data	LC, SC
Section 5	Redundancy matrix of the least squares algorithm for spatial data optimization and its potential.	5.1	Determination of the redundancy matrix for parametric and correlated versions of least squares data optimization.	LC, SC
		5.2	A posteriori analysis of the scale accuracy index using the redundancy matrix.	LC, SC
Section 6	Spatial position of a point and indicators of spatial position accuracy.	6.1	Position of a point in one-dimensional, two-dimensional and three-dimensional space. Mean square errors (MSE) of the position of a point in space.	LC, SC
		6.2	Relative position coefficient of points in space. Relative distance coefficient of points. Relative orientation coefficient of a line connecting two points in two-dimensional and three-dimensional space.	LC, SC
Section 7	A synthesized version of the correlated version of least squares optimization and spatial data analysis.	7.1	Derivation of the algorithm of the synthesized variant of the correlated version. Step-by-step controls of the algorithm implementation.	LC, SC
		7.2	Finding a redundancy matrix using blocks of an inverse synthesized matrix. A posteriori assessment of data accuracy.	LC, SC
Section 8	Synthesized version of the parametric version of the least squares optimization and analysis of spatial data	8.1	Derivation of the algorithm of the synthesized variant of the parametric version. Step-by-step controls of the algorithm implementation.	LC, SC
		8.2	Finding a Redundancy Matrix Using Inverse Synthesized Matrix Blocks. A Posteriori Estimation of Data Accuracy	LC, SC

Section number	Name of the discipline section	Section Contents (Topics)		Type of academic work*
Section 9	Universal Synthesized Algorithm for OLS Optimization and Spatial Data Analysis	9.1	Derivation of the universal synthesized algorithm. Step-by-step controls of the algorithm implementation. Finding the matrix redundancies using inverse synthesized matrix blocks.	LC, SC
		9.2	A posteriori estimation of data accuracy. Application of a universal synthesized algorithm for least squares optimization of data in "free" geodetic constructions	LC, SC

* - filled in only for FULL-TIME education: LC – lectures; LW – laboratory work; SC– practical/seminar classes.

6. LOGISTIC AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support of the discipline

Audience type	Equipping the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	An auditorium for conducting lecture-type classes, equipped with a set of specialized furniture; a board (screen) and technical means for multimedia presentations.	
Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with a set of specialized furniture and technical means for multimedia presentations.	
For independent work	A classroom for independent work of students (can be used for conducting seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the audience for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. Arlinghaus SL, Kerski JJ Spatial mathematics: Theory and practice through mapping. – CRC Press, 2013.

2. Pebesma E., Bivand R. Spatial data science: With applications in R. – Chapman and Hall/CRC, 2023.

Further reading:

1. Legendre G. (ed.). Mathematics of space. – John Wiley & Sons, 2011.

2. Wilf HS Mathematics for the physical sciences. – Courier Corporation, 2013

Resources of the information and telecommunications network "Internet":

1. RUDN University EBS and third-party EBSs to which university students have access on the basis of concluded agreements

- Electronic library system of RUDN - ELS RUDN https://mega.rudn.ru/MegaPro/Web
- Electronic library system "University library online"http://www.biblioclub.ru
- EBS Yuraithttp://www.biblio-online.ru
- Electronic Library System "Student Consultant" www.studentlibrary.ru
- EBS "Znanium"https://znanium.ru/

2. Databases and search engines

- Sage https://journals.sagepub.com/
- Springer Nature Link https://link.springer.com/
- Wiley Journal Database https://onlinelibrary.wiley.com/
- Scientometric database Lens.org https://www.lens.org

Educational and methodological materials for independent work of students in mastering a discipline/module:*

1. Lecture course on the subject "Spatial Mathematics".

* - all educational and methodological materials for independent work of students are posted in accordance with the current procedure on the discipline page in TUIS!

DEVELOPER:

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