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

NUMERICAL METHODS FOR SOLVING MATHEMATICAL MODELING PROBLEMS

(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 course " Numerical Methods for Solving Mathematical Modeling Problems" 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 course is implemented by the Department of Mechanics and Control Processes. The course consists of 6 sections and 45 topics and is aimed at studying the theory and acquiring skills in the practical application of research methods and solving extremum problems using a computer. Specific iterative direct and indirect numerical optimization methods are studied.

The purpose of mastering the discipline is to obtain the necessary stock of initial basic knowledge on the main methods of numerical solution of optimization problems of functions of one variable and several variables, methods of numerical optimization for convex functions, methods of numerical solution of problems of variational calculus and optimal control, to obtain knowledge on the rational and effective use of the obtained knowledge when implementing the corresponding algorithms on a computer; to form in students an idea of the choice of the necessary method in a specific situation depending on the formulation of the problem. The main objectives of the course are: to create favorable conditions for self-development of students; to acquaint students with the basic concepts of modern mathematics; to develop in students the skills of numerical solution of optimization problems.

2. REQUIREMENTS TO THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline " Numerical Methods for Solving Mathematical Modeling Problems" 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 command 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 problems in technical systems.
GPC-8	Able to select methods and develop control systems for complex technical objects and technological processes	GPC-8.1 Knows the basic methods used to develop control systems for complex technical objects and technological processes; GPC-8.2 Can develop control systems for complex technical objects and technological processes; GPC-8.3 Has the skills to select methods and develop control systems for complex technical objects and technological processes.;

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

Discipline " Numerical Methods for Solving Mathematical Modeling Problems " 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 " Numerical Methods for Solving Mathematical Modeling Problems ".

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		Advanced Methods of Space Flight Mechanics; Advanced Methods of Earth Remote Sensing; Geoinformation Systems and Applications; Undergraduate Training;
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them		Undergraduate Training; Dynamics and Control of Space Systems;
GPC-8	Able to select methods and develop control systems for complex technical objects and technological processes		Undergraduate Training;

* - 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 course “Numerical Methods for Solving Mathematical Modeling Problems” is 5 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	*34*		*34*
Lectures (LC)	17		17
Laboratory work (LW)	0		0
Practical/seminar classes (SC)	17		17
Independent work of students, academic hours	*110*		*110*
Control (exam/test with assessment), academic hours	*36*		*36*
General complexity of the discipline	**ac.h.**	***180***	*180*
	credit.ed.	***5***	*5*

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	Methods for minimizing functions of one variable	1.1	Statement of the problem. Classical method	LK, SC
		1.2	Bisection method	LK, SC
		1.3	Golden Section Method	LK, SC
		1.4	Broken line method	LK, SC
		1.5	Coating method	LK, SC
		1.6	Convex functions of one variable	LK, SC
		1.7	Method of tangents	LK, SC
Section 2	Classical theory of extremum of functions of several variables	2.1	Statement of the problem	LK, SC
		2.2	Weierstrass's theorem	LK, SC
		2.3	Classical method for solving problems on unconditional extremum	LK, SC
		2.4	Problems on conditional extremum	LK, SC
		2.5	Necessary conditions of the first and second order	LK, SC
		2.6	Sufficient conditions for an extremum	LK, SC
Section 3	Methods for minimizing functions of several variables	3.1	Gradient method	LK, SC
		3.2	Gradient projection method	LK, SC
		3.3	Conditional gradient method	LK, SC
		3.4	Method of possible directions	LK, SC
		3.5	Proximal method	LK, SC
		3.6	Linearization method	LK, SC
		3.7	Quadratic programming	LK, SC
		3.8	Method of conjugate directions	LK, SC
		3.9	Newton's method	LK, SC
		3.10	Continuous methods with variable metric	LK, SC
		3.11	Coordinate descent method	LK, SC
		3.12	Covering method in multidimensional problems	LK, SC
		3.13	Modified Lagrange Function Method	LK, SC
		3.14	Penalty function method	LK, SC
		3.15	Proof of necessary conditions for first and second order extremum using penalty functions	LK, SC
		3.16	Barrier function method	LK, SC
		3.17	Loaded function method	LK, SC
		3.18	Random search method	LK, SC
Section 4	Dynamic programming	4.1	Bellman's diagram	LK, SC
		4.2	The problem of synthesis for discrete systems	LK, SC
		4.3	Moiseev's scheme	LK, SC
		4.4	Synthesis problem for continuous-time systems	LK, SC
		4.5	Sufficient conditions for optimality	LK, SC
Section 5	Pontryagin's maximum principle	5.1	Statement of the optimal control problem	LK, SC
		5.2	Formulation of the maximum principle	LK, SC
		5.3	Proof of the maximum principle	LK, SC
		5.4	Maximum principle for optimal control problems with phase constraints	LK, SC
		5.5	The relationship between the maximum principle and the classical calculus of variations	LK, SC
Section 6	Application of the maximum principle to optimization problems	6.1	Reduction of an optimization problem to a boundary value problem of the maximum principle	LK, SC
		6.2	Shooting method for numerical solution of boundary value problem of maximum principle	LK, SC
		6.3	Modifications of Newton's method: Isaev-Sonin modification, Fedorenko normalization	LK, SC
		6.4	Runge-Kutta method for solving Cauchy problems	LK, SC

* - filled in only for FULL-TIME education: LK – 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. Bakhvalov Nikolay Sergeevich. Numerical methods: Textbook / N.S. Bakhvalov, N.P. Zhidkov, G.M. Kobelkov; N.S. Bakhvalov and others - 4th ed. - M.: Nauka, 1987. - 636 p. : ill. - (Classical university textbook). -ISBN 5-94774-396-5: 244.53.

2. Kalitkin Nikolay Nikolaevich. Numerical methods: Textbook for universities / N.N. Kalitkin; Ed.A.A. Samarsky. - M.: Nauka, 1978. - 512 p. : ill. - 1.30.

Further reading:

1. Fedorenko R.P. Approximate solutions of optimal control problems.M., Nauka, 1978.

2. A. N. Kolmogorov, S. V. Fomin. Elements of the Theory of Functions and Functional Analysis. Lomonosov Moscow State University. - 7th ed. - Moscow: Fizmatlit, 2004. - 572 p.

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 "Numerical methods for solving mathematical modeling problems".

* - 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:

Associate Professor		Saltykova Olga Alexandrovna
Position, Department	*Signature*	*Surname I.O.*

HEAD OF THE DEPARTMENT:

Head of Department		Razumny Yuri Nikolaevich
Position of the Department	*Signature*	*Surname I.O.*

HEAD OF THE EP HE:

Head of Department		Razumny Yuri Nikolaevich
Position, BUP	*Signature*	*Surname I.O.*