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

Academy of Engineering
(name of the main educational unit (POU) - developer of the EP HE)

COURSE SYLLABUS

NUMERICAL METHODS
(name of discipline/module)

Recommended by the Didactic Council for the Education Field of:

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

The course instruction is implemented within the professional education programme of higher education:

DATA ENGINEERING AND SPACE SYSTEMS CONTROL
(name (profile/specialization) EP HE)

2024

1. GOAL OF DISCIPLINE MASTERING

The discipline “Numerical Methods” is included in the bachelor’s program “Data Engineering and Space Systems Control” in the direction of 27.03.04 “Control in Technical Systems” and is studied in the 5th semester of the 3rd year. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 10 sections and 65 topics and is aimed at studying classical algorithms for solving optimization problems, including the most effective and most important methods from a methodological point of view.

The goal of mastering the discipline is to obtain the necessary knowledge to implement numerical optimization methods in algorithmic programming languages

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline “Numerical Methods” is aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies formed in students when mastering the discipline (results of mastering the discipline)

Cipher	**Competence**	**Indicators of Competency Achievement** (within this discipline)
GPC -2	Able to formulate tasks of professional activity based on knowledge, specialized sections of mathematical and natural science disciplines (modules)	GPC -2.1 Proficient in mathematical methods, programming fundamentals and specialized programming systems for implementing algorithms for solving applied problems; GPC -2.2 Able to select and adapt mathematical methods and software to solve practical problems; GPC -2.3 Possesses the skills of developing and implementing algorithms for solving applied problems in the field of professional activity;
GPC -3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	GPC-3.1 Knows the theoretical foundations and principles of mathematical modeling; GPC -3.2 Able to develop and use methods of mathematical modeling, information technologies to solve problems of applied mathematics; GPC-3.3 Possesses practical skills in solving problems of applied mathematics, methods of mathematical modeling, information technologies and the basics of their use in professional activities, professional thinking skills and an arsenal of methods and approaches necessary for the adequate use of methods of modern mathematics in theoretical and applied problems;
PC-1	Capable of collecting, processing and interpreting modern scientific research data necessary to draw conclusions on relevant scientific research, including Earth remote sensing data	PC-1.1 Knows modern methods of how to collect, process and interpret modern scientific research data necessary to form conclusions on relevant scientific research; PC-1.2 Able to apply modern methods and tools for processing and interpreting scientific research data; PC-1.3 Possesses the basic skills of collecting, processing and interpreting modern scientific research data necessary to form conclusions on relevant scientific research;

3. PLACE OF DISCIPLINE IN THE STRUCTURE OF HE EP

Discipline "Numerical methods" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the educational program of higher education, students also master other disciplines and/or practices that contribute to achieving the planned results of mastering the discipline “Numerical Methods”.

Table 3.1. List of components of EP HE that contribute to achieving the planned results of mastering the discipline

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
GPC -2	Able to formulate tasks of professional activity based on knowledge, specialized sections of mathematical and natural science disciplines (modules)	Mathematical analysis; Space Flight Mechanics; Algebra and Geometry; Analysis of Geoinformation Data;	Research work / Scientific research work; Technological Training; Undergraduate practice / Pre-graduate practice; Space Flight Mechanics; Automatic Control Theory; Equations of mathematical physics; Analysis of Geoinformation Data;
GPC -3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	Mathematical analysis; Space Flight Mechanics; Theoretical Mechanics; Algebra and Geometry; Theory of Probability and Mathematical Statistics; Differential equations; complex analysis; Analysis of Geoinformation Data;	Space Flight Mechanics; Automatic Control Theory; Equations of mathematical physics; Optimal Control Methods; Analysis of Geoinformation Data; Research work / Scientific research work; Technological Training; Undergraduate practice / Pre-graduate practice;
PC-1	Capable of collecting, processing and interpreting modern scientific research data necessary to draw conclusions on relevant scientific research, including Earth remote sensing data	Space Flight Mechanics; Computer Science and Programming; *Discrete mathematics***; *Discrete Math***; Analysis of Geoinformation Data;	Research work / Scientific research work; Technological Training; Undergraduate practice / Pre-graduate practice; Space Flight Mechanics; Automatic Control Theory; *Virtual and Augmented Reality Technology***; *Virtual and augmented reality technologies***; Optimal Control Methods; Analysis of Geoinformation Data;

* - to be filled out in accordance with the competency matrix and SUP EP VO

** - elective disciplines/practices

4. SCOPE OF DISCIPLINE AND TYPES OF STUDY WORK

The total labor intensity of the "Numerical Methods" discipline is "3" credit units.

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

Type of educational work	**TOTAL,**ac.ch.		**Semester(s)**
			5
Contact work, ac.ch.	*54*		*54*
Lectures (LC)	18		18
Laboratory work (LR)	36		36
Practical/seminar sessions (SZ)	0		0
Independent work of students, ac.ch.	*54*		*54*
Control (exam/test with assessment), academic degree.	*0*		*0*
Total labor intensity of the discipline	**ac.ch.**	***108***	*108*
	credit units	***3***	*3*

5. CONTENT OF DISCIPLINE

Table 5.1. Contents of the discipline (module) by type of academic works

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
Section 1	Numerical optimization methods	1.1	Optimization concept	LK, LR
		1.2	Statement of the optimization problem	LK, LR
		1.3	Numerical approach to solving the optimization problem	LK, LR
Section 2	One-dimensional optimization methods	2.1	Svenn's algorithm for finding the uncertainty interval	LK, LR
		2.2	One-dimensional optimization methods	LK, LR
		2.3	Halving method	LK, LR
		2.4	Dichotomy method	LK, LR
		2.5	Golden ratio method	LK, LR
		2.6	Fibonacci method	LK, LR
Section 3	Multidimensional optimization methods	3.1	Zero-order multidimensional optimization methods	LK, LR
		3.2	Hooke–Jeeves configuration method	LK, LR
		3.3	Nelder–Mead deformable polyhedron method	LK, LR
		3.4	Rosenbrock method	LK, LR
		3.5	Powell's conjugate directions method	LK, LR
		3.6	Random Search Methods	LK, LR
		3.7	Adaptive random search method	LK, LR
		3.8	Random search method with return if step fails	LK, LR
		3.9	Best sample method	LK, LR
		3.10	Statistical gradient method	LK, LR
		3.11	Random search method with guiding hypersquare	LK, LR
Section 4	Numerical methods of differentiation and integration	4.1	Numerical methods for approximate calculation of derivatives	LK, LR
		4.2	Difference formula for calculating the first partial derivative	LK, LR
		4.3	Difference formula for calculating the second derivative	LK, LR
		4.4	Numerical methods for solving ODEs	LK, LR
		4.5	Cauchy problem	LK, LR
		4.6	Numerical solution of the Cauchy problem	LK, LR
		4.7	Euler method	LK, LR
		4.8	Improved Euler Methods	LK, LR
Section 5	First order optimization methods	5.1	First order optimization methods	LK, LR
		5.2	Gradient descent method with constant step	LK, LR
		5.3	Coordinate-wise gradient descent method	LK, LR
		5.4	Steepest gradient descent method	LK, LR
		5.5	Gauss–Seidel method	LK, LR
		5.6	Fletcher–Reeves method	LK, LR
Section 6	Second order optimization methods	6.1	Second order optimization methods	LK, LR
		6.2	Newton's method	LK, LR
		6.3	Newton–Raphson method	LK, LR
		6.4	Marquardt method	LK, LR
Section 7	Conditional optimization methods	7.1	Penalty function methods for conditional optimization	LK, LR
		7.2	Method of penalty functions (method of external penalties)	LK, LR
		7.3	Barrier function method (internal penalty method)	LK, LR
		7.4	Combined penalty function method	LK, LR
Section 8	Linear programming problems	8.1	Statement of the linear programming problem	LK, LR
		8.2	Canonical form of writing a linear programming problem and methods of reduction to it	LK, LR

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
		8.3	Simplex method for solving a linear programming problem	LK, LR
		8.4	Algorithm for obtaining an admissible initial basis when solving a linear programming problem using the simplex method	LK, LR
Section 9	Discrete optimization problems	9.1	Concept and class of discrete optimization problems	LK, LR
		9.2	Classic discrete optimization problems	LK, LR
		9.3	Methods for solving discrete optimization problems	LK, LR
		9.4	Heuristic algorithms	LK, LR
		9.5	Branch and bound method	LK, LR
		9.6	Dynamic programming method	LK, LR
Section 10	Modern metaheuristic algorithms for global optimization	10.1	Class of metaheuristic global optimization algorithms	LK, LR
		10.2	Evolutionary and population optimization methods	LK, LR
		10.3	Evolutionary algorithms	LK, LR
		10.4	Genetic algorithm	LK, LR
		10.5	Crossing and mutation operations in a genetic algorithm	LK, LR
		10.6	Population algorithms	LK, LR
		10.7	Particle swarm method	LK, LR
		10.8	Scheme for modifying a possible solution in the particle swarm method	LK, LR
		10.9	Bee algorithm	LK, LR
		10.10	Gray wolf algorithm	LK, LR
		10.11	Cat Optimization Algorithm	LK, LR
		10.12	Bat-inspired method	LK, LR
		10.13	Whale optimization algorithm	LK, LR

* - to be filled out only for full-time education: LC – lectures; LR – laboratory work; SZ – practical/seminar classes.

6. MATERIAL AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support of the discipline

Audience type	Auditorium equipment	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; board (screen) and technical means of multimedia presentations.	
Computer class	A computer class for conducting classes, group and individual consultations, ongoing monitoring and intermediate certification, equipped with personal computers ([Parameter] pcs.), a whiteboard (screen) and technical means for multimedia presentations.	

Audience type	Auditorium equipment	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, ongoing monitoring and intermediate certification, equipped with a set of specialized furniture and technical means for multimedia presentations.	
For independent work	An auditorium for independent work by students (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to EIOS.	

* - the audience for independent work of students is MANDATORY!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF DISCIPLINE

Main literature:

1. Attetkov A.V., Galkin S.V., Zarubin V.S. Optimization methods.M.: Publishing house of MSTU im. N.E. Bauman. 2001. 440 p.

2. Panteleev A.V., Letova T.A. Optimization methods in examples and problems.M.: Higher school. 2002. 544 p.

3. Kornienko V.P. Optimization methods.M.: Higher school. 2007. 664 p.

4. Sobol B.V., Meskhi B.Ch., Kanygin G.I. Optimization methods. Workshop. Rostov-on-Don: Phoenix Publishing House.2009. 380 p.

Additional literature:

1. Gladkov L.A., Kureichik V.V., Kureichik V.M. Genetic algorithms: M.: Fizmatlit, 2006.-319 p.

2. Chernorutsky I.G. Optimization methods in control theory

3. Izmailov A.F., Solodov M.V. Numerical optimization methods

4. Andreeva E.A., Tsiruleva V.M. Calculus of variations and optimization methods

Resources of the information and telecommunications network "Internet":

1. EBS of RUDN University and third-party EBS, to which university students have access based on concluded agreements

- Electronic library system of RUDN University - EBS RUDN Universityhttp://lib.rudn.ru/MegaPro/Web
- EBS "University Library Online"http://www.biblioclub.ru
- EBS Lawhttp://www.biblio-online.ru
- EBS "Student Consultant"www.studentlibrary.ru
- EBS "Trinity Bridge"

2. Databases and search engines

- electronic fund of legal and regulatory technical documentationhttp://docs.cntd.ru/
- Yandex search enginehttps://www.yandex.ru/
- search systemGoogle https://www.google.ru/
- abstract databaseSCOPUS http://www.elsevierscience.ru/products/scopus/

Educational and methodological materials for students' independent work when mastering a discipline/module:*

1. A course of lectures on the discipline "Numerical methods".

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

8. ASSESSMENT MATERIALS AND POINT-RATING SYSTEM FOR ASSESSING THE LEVEL OF COMPETENCIES FOR A DISCIPLINE

Evaluation materials and point-rating system* for assessing the level of development of competencies (parts of competencies) based on the results of mastering the discipline"Numerical methods" are presented in the Appendix to this Work Program of the discipline.

* - OM and BRS are formed on the basis of the requirements of the relevant local regulatory act of RUDN University.

DEVELOPER:

Assistant professor		Saltykova Olga Alexandrovna
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HEAD OF DEPARTMENT:

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