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 FOR SOLVING MATHEMATICAL MODELING PROBLEMS
(name of discipline/module)

Recommended by the Didactic Council for Education Program of:

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

The discipline is mastered as part of the implementation of the main professional educational program of higher education:

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

2024

1. GOAL OF DISCIPLINE MASTERING

The discipline “Numerical Methods for Solving Mathematical Modeling Problems” is included in the master’s program “Data Science and Space Engineering” 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 Mechanics and Control Processes. The discipline consists of 6 sections and 45 topics and is aimed at studying theory and gaining 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 for students to obtain the necessary stock of initial basic knowledge on the basic methods of numerical solution of problems of optimization of functions of one variable and many variables, methods of numerical optimization for convex functions, methods of numerical solution of problems of the calculus of variations and optimal control, obtaining knowledge on the rational and effective use of the obtained knowledge in implementing relevant algorithms on a computer; to form in students an idea of choosing the necessary method in a specific situation, depending on the formulation of the problem. The main objectives of the course are: creating favorable conditions for students’ self-development; introduce students to the basic concepts of modern mathematics; development of students' skills in numerical solution of optimization problems.

2. REQUIREMENTS FOR 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 formed in students when mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within 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, regulations 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 Possesses tools for analyzing management 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 for solving control problems in technical systems;; GPC-2.2 Able to justify methods for solving control problems in technical systems;; GPC-2.3 Knows 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 Able to 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 DISCIPLINE IN THE STRUCTURE OF HE EP

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 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 for solving mathematical modeling problems."

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

* - 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 complexity of the discipline “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 study.

Type of educational work	**TOTAL,**ac.ch.		**Semester(s)**
			1
Contact work, ac.ch.	*34*		*34*
Lectures (LC)	17		17
Laboratory work (LR)	0		0
Practical/seminar sessions (SZ)	17		17
Independent work of students, ac.ch.	*110*		*110*
Control (exam/test with assessment), academic degree.	*36*		*36*
Total labor intensity of the discipline	**ac.ch.**	***180***	*180*
	credit units	***5***	*5*

5. CONTENT OF DISCIPLINE

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

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
Section 1	Methods for minimizing functions of one variable	1.1	Formulation of the problem. Classic method	LC, NW
		1.2	Bisection method	LC, NW
		1.3	Golden ratio method	LC, NW
		1.4	Polyline method	LC, NW
		1.5	Coating method	LC, NW
		1.6	Convex functions of one variable	LC, NW
		1.7	Tangent method	LC, NW
Section 2	Classical theory of extremum of functions of several variables	2.1	Formulation of the problem	LC, NW
		2.2	Weierstrass's theorem	LC, NW
		2.3	Classical method for solving unconditional extremum problems	LC, NW
		2.4	Conditional extremum problems	LC, NW
		2.5	Necessary conditions of the first and second order	LC, NW
		2.6	Sufficient conditions for an extremum	LC, NW
Section 3	Methods for minimizing functions of several variables	3.1	Gradient method	LC, NW
		3.2	Gradient projection method	LC, NW
		3.3	Conditional Gradient Method	LC, NW
		3.4	Possible directions method	LC, NW
		3.5	Proximal method	LC, NW
		3.6	Linearization method	LC, NW
		3.7	Quadratic programming	LC, NW
		3.8	Conjugate Directions Method	LC, NW
		3.9	Newton's method	LC, NW
		3.10	Continuous Variable Metric Methods	LC, NW
		3.11	Coordinate descent method	LC, NW
		3.12	Covering method in multidimensional problems	LC, NW
		3.13	Method of modified Lagrange functions	LC, NW
		3.14	Penalty function method	LC, NW
		3.15	Proof of necessary conditions for an extremum of the first and second orders using penalty functions	LC, NW
		3.16	Barrier function method	LC, NW
		3.17	Loaded Function Method	LC, NW
		3.18	Random search method	LC, NW
Section 4	Dynamic programming	4.1	Bellman circuit	LC, NW
		4.2	Synthesis problem for discrete systems	LC, NW
		4.3	Moiseev's scheme	LC, NW
		4.4	Synthesis problem for continuous time systems	LC, NW
		4.5	Sufficient conditions for optimality	LC, NW
Section 5	Pontryagin's maximum principle	5.1	Formulation of the optimal control problem	LC, NW
		5.2	Formulation of the maximum principle	LC, NW
		5.3	Proof of the maximum principle	LC, NW
		5.4	The maximum principle for optimal control problems with phase constraints	LC, NW
		5.5	Relationship between the maximum principle and classical calculus of variations	LC, NW
Section 6	Application of the maximum principle to optimization problems	6.1	Reducing the optimization problem to a maximum principle boundary value problem	LC, NW
		6.2	Shooting method for numerical solution of maximum principle boundary value problem	LC, NW
		6.3	Modifications of Newton's method: Isaev-Sonin modification, Fedorenko normalization	LC, NW
		6.4	Runge-Kutta method for solving Cauchy problems	LC, NW

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

Additional literature:

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

2. A. N. Kolmogorov, S. V. Fomin. Elements of the theory of functions and functional analysis. Moscow State University named after M. V. Lomonosov.— 7th ed. - M.: Fizmatlit, 2004. - 572 p.

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 for solving mathematical modeling problems."

* - 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 for solving mathematical modeling problems" 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.

DEVELOPERS:

Assistant professor		Saltykova Olga Alexandrovna
Position	*Signature*	*Last name I.O.*
Assistant professor		Demidov Alexander Sergeevich
Position	*Signature*	*Last name I.O*

HEAD OF DEPARTMENT:

Head of the department		Razumny Yuri Nikolaevich
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HEAD OF EP HE:

Professor		Razumny Yuri Nikolaevich
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