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

OPTIMAL CONTROL METHODS
(name of discipline/module)

Recommended for the field of study/specialty:

27.03.04 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):

DATA SCIENCE AND SPACE SYSTEMS
(name (profile/specialization) of the educational institution of higher education)

2025

1. THE GOAL OF MASTERING THE DISCIPLINE

The discipline "Optimal Control Methods" is included in the bachelor's program "Data Science and Space Systems" in the direction 27.03.04 "Control in Technical Systems" and is studied in semesters 6, 7 of the 3rd and 4th years. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 3 sections and 23 topics and is aimed at studying the fundamental principles of the maximum principle of L.S. Pontryagin, dynamic programming, numerical methods of optimal control, analysis of the main methods for solving typical problems and familiarization with the area of their application in professional activities.

The purpose of mastering the discipline is to develop fundamental knowledge and skills in applying methods for solving problems necessary for professional activity, and to increase the general level of literacy of students in control methods.

2. REQUIREMENTS TO THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline "Optimal Control Methods" 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)
UC-12	Able to search for the necessary sources of information and data, perceive, analyze, remember 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	UC-12.1 Searches for the necessary sources of information and data, perceives, analyzes, remembers and transmits information using digital means, as well as using algorithms when working with data obtained from various sources in order to effectively use the information obtained to solve problems; UC-12.2 Conducts an assessment of information, its reliability, builds logical conclusions based on incoming information and data;
GPC-11	Able to understand the principles of operation of modern information technologies and use them to solve problems of professional activity	GPC-11.1 Knows digital methods and technologies used in professional activities; GPC-11.2 Able to apply digital methods and technologies in professional activities to study and model objects of professional activity, analyze data, and present information; GPC-11.3 Confidently uses digital methods and technologies in professional activities (in the field of control in technical systems) for: studying and modeling objects of professional activity, data analysis, presentation of information;
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, skills of professional thinking and an arsenal of methods and approaches necessary for the adequate use of methods of modern mathematics in theoretical and applied problems;
GPC-8	Capable of adjusting measuring and control equipment and	GPC-8.1 Knows the parameters and characteristics of measuring and control equipment and complexes;

Cipher	Competence	Indicators of Competence Achievement (within the framework of this discipline)
	systems, and performing their routine maintenance	GPC-8.2 Can perform routine maintenance of measuring and control equipment and complexes; GPC-8.3 Ensures the adjustment of measuring and control equipment and complexes and their routine maintenance;
GPC-9	Capable of performing experiments according to specified methods and processing the results using modern information technologies and technical means	GPC-9.1 Knows modern information technologies and technical means; GPC-9.2 Able to apply modern information technologies and technical means to process experimental results; GPC-9.3 Possesses modern information technologies and technical means for performing experiments and processing results;
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 collecting, processing and interpreting data from modern scientific research necessary for drawing 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 data from modern scientific research necessary for drawing conclusions on relevant scientific research;
PC-4	Able to formulate, analyze and solve engineering problems in the field of ballistics, motion mechanics and spacecraft motion control based on professional knowledge	PC-4.1 Knows the basic concepts and basic algorithms for solving problems in the field of ballistics, motion mechanics and motion control based on automated and automatic systems; PC-4.2 Able to solve engineering problems of an analytical nature in the field of ballistics, motion mechanics and control of spacecraft motion based on professional knowledge; PC-4.3 Possesses the skills to use mathematical methods for processing information obtained as a result of experimental research, the basic methods of analyzing the mechanics of motion and controlling the motion of spacecraft based on standard methods and software packages;

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

Discipline "Methods of optimal control" 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 "Methods of Optimal Control".

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*
UC-12	Able to search for the necessary sources of information and data, perceive, analyze, remember 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	Research work / Scientific research work; Automatic Control Theory; Analysis of Geoinformation Data; *Fundamentals of Information Security and Cyber Resilience***; *Fundamentals of Information Security and Cyber Resilience***;	Technological Training; Undergraduate Training;

Cipher	Name of competence	Previous courses/modules, practices*	Subsequent disciplines/modules, practices*
	solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data		
GPC-3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	Research work / Scientific research work; Mathematical analysis; Space Flight Mechanics; Theoretical Mechanics; Numerical Methods; Automatic Control Theory; Algebra and Geometry; Theory of Probability and Mathematical Statistics; Differential equations; Complex analysis; Analysis of Geoinformation Data;	Technological Training; Undergraduate Training;
GPC-8	Capable of adjusting measuring and control equipment and systems, and performing their routine maintenance		Undergraduate Training;
GPC-9	Capable of performing experiments according to specified methods and processing the results using modern information technologies and technical means	Computer Science and Programming; Analysis of Geoinformation Data; Basic Military Training. Life Safety;	Undergraduate Training; Technological Training;
GPC-11	Able to understand the principles of operation of modern information technologies and use them to solve problems of professional activity	Space Flight Mechanics;	Undergraduate Training; Technological Training;
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	Research work / Scientific research work; Space Flight Mechanics; Numerical Methods; Automatic Control Theory; Computer Science and Programming; *Discrete Mathematics***; *Discrete Mathematics***; Analysis of Geoinformation Data;	Technological Training; Undergraduate Training;
PC-4	Able to formulate, analyze and solve engineering problems in the field of ballistics, motion mechanics and spacecraft motion control based on professional knowledge	Research work / Scientific research work; Space Flight Mechanics; Theoretical Mechanics;	Technological Training; 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 "Optimal Control Methods" discipline is 10 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)**	
			6	**7**
Contact work, academic hours	*162*		*72*	*90*
Lectures (LC)	72		36	36
Laboratory work (LW)	72		36	36
Practical/seminar classes (SC)	18		0	18
Independent work of students, academic hours	*144*		*81*	*63*
Control (exam/test with assessment), academic hours	*54*		*27*	*27*
General complexity of the discipline	**ac.h.**	***360***	*180*	*180*
	credit.ed.	***10***	*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	Optimal control theory. Maximum principle of L.S. Pontryagin.	1.1	Statement of optimal control problems. Basic concepts. Examples of optimal control problems.	LC, LW, SC
		1.2	Problems with a free right end of the trajectory. Formula for increment of the functional.	LC, LW, SC
		1.3	L.S. Pontryagin's maximum principle for problems with a free right end. Formulation and proof.	LC, LW, SC
		1.4	Linear problems with free right end. The maximum principle as a necessary and sufficient condition.	LC, LW, SC
		1.5	Formulation of the maximum principle for various classes of optimal control problems: a) two-point problems; b) optimal speed problem; c) problems with boundary conditions, transversality conditions; d) autonomous and non-autonomous systems; d) problems with fixed and non-fixed process completion time; e) problems with integral and terminal functional; g) problems with parameters.	LC, LW, SC
		1.6	Examples of optimal control problems. The problem of speed of response.	LC, LW, SC
		1.7	The concept of optimal control synthesis.	LC, LW
		1.8	The connection of the maximum principle with the classical calculus of variations. Derivation of the Euler equation and the Legendre-Clebsch conditions from the maximum principle. The Jacobi condition.	LC, LW, SC
Section 2	Dynamic programming	2.1	Controlled multi-step processes. Optimality principle.	LC, LW, SC
		2.2	Dynamic programming method for multi-step control processes.	LC, LW
		2.3	Dynamic programming method for optimal control problems.	LC, LW, SC
		2.4	Bellman differential equation. Statement of problems for the Bellman equation. Examples.	LC, LW, SC
		2.5	The relationship between the dynamic programming method and the maximum principle. Derivation of transversality conditions using the dynamic programming method.	LC, LW, SC
		2.6	Linear control systems with quadratic functional. Construction of optimal control synthesis.	LC, LW, SC
Section 3	Numerical methods of optimal control	3.1	Numerical methods based on reducing optimal control problems to boundary value problems using the maximum principle.	LC, LW, SC
		3.2	Using methods for solving systems of algebraic equations to solve boundary value problems. Newton's method and its modifications.	LC, LW, SC
		3.3	Numerical methods for minimizing functions of many variables. The concept of linear and nonlinear programming. Gradient method. Penalty function method.	OK
		3.4	Numerical methods based on variation of control functions. Gradient method in control space. Accounting for constraints on control functions. Accounting for boundary conditions and phase constraints by the penalty function method.	LC, LW, SC

Section number	Name of the discipline section	Section Contents (Topics)		Type of academic work*
			Accounting for boundary conditions by the gradient projection method.	
		3.5	The method of successive approximations in the space of control functions. Methods for improving convergence and modifying the method. Examples.	LC, LW, SC
		3.6	Small parameter method for weakly controlled systems.	LC, SC
		3.7	Numerical methods based on variation in space of phase coordinates. Dynamic programming method. Complete and partial enumeration. "Wandering tube" method.	LC, LW, SC
		3.8	The concept of an elementary operation and methods for constructing it. Construction of an elementary operation for flight dynamics problems.	LC, LW, SC
		3.9	Method of local variations. Application of the method of local variations to various variational problems. Variational problems with non-additive functionals. Variational problems in partial derivatives.	LC, LW, 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.	
Computer class	A computer room for conducting classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with personal computers (15 units), 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	

Audience type	Equipping the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
	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. Pontryagin L.S., Boltyansky V.G., Gamkrelidze R.V., Mishchenko E.F. Mathematical theory of optimal processes.M.: Science, 1969.

2. Ivanov V.A., Faldin P.V. Theory of optimal automatic control systems.M.: NaUCa, 1981. 336 p.

3. Roytenberg Ya.N. Automatic control, Moscow: NaUCa, 1971.396 pp.

4. Afanasyev V.N., Kolmanovsky V.B., Nosov V.R. Mathematical theory of control systems design.M.: Higher School, 2003.

Further reading:

1. Gelfand I.M., Fomin S.V. Calculus of variations.M.: Fizmatlit, 1961.

2. Boltyansky V.G. Mathematical methods of optimal control.M.: Science, 1969.

3. Bellman R., Dreyfus S. Applied problems of dynamic programming.M.: Science, 1965.

4. Moiseev N.N. Elements of the theory of optimal systems.M.: Science, 1975.

5. Chernousko F.L., BanichUC N.V. Variational problems of mechanics and control.Numerical methods. Moscow: NaUCa, 1973.

6. Chernousko F.L., Akulenko L.D., Sokolov B.N. Control of oscillations. Moscow: NaUCa, 1980.

7. Chernousko F.L. Estimation of the phase state of dynamic systems.M.: Fizmatlit, 1988.

8. Chernousko F.L., Ananevsky I.M., Reshmin S.A. Methods of control of nonlinear mechanical systems.M.: Fizmatlit, 2006.

9. Chernousko FL, Ananievski IM, Reshmin SA Control of Nonlinear Dynamical Systems. Methods and Applications. Berlin, Heidelberg: Springer, 2008, 396 p.

10. Lee E.B., Marcus L. Fundamentals of Optimal Control Theory / Translated from English.M.: NaUCa, 1972. 576 p.

11. Pontryagin L.S. The maximum principle. Moscow: Fund for Mathematical Education and Enlightenment, 1998.

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 RUDNhttp://lib.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
- Electronic library system "Troitsky Bridge"

2. Databases and search engines

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

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

1. Lecture course on the subject "Optimal control methods".

* - 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, Department	*Signature*	*Surname I.O.*