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

AUTOMATIC CONTROL THEORY
(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 “Automatic Control Theory” 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 and 6th semesters of the 3rd year. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 10 sections and 76 topics and is aimed at studying the fundamental principles of mathematical models and dynamic characteristics of linear stationary automatic control systems, stability of linear systems, quality of automatic control systems, correction of automatic control systems, mathematical models of nonlinear deterministic systems, stability of nonlinear systems, research random processes in automatic control systems, synthesis of automatic control systems and optimization, research of discrete automatic control systems, non-stationary systems, general information, analysis of the basic methods for solving typical problems and familiarity with the scope of their application in professional activities.

The purpose of mastering the discipline is to develop fundamental knowledge and skills in applying problem-solving methods necessary for professional activities, increasing the overall level of students’ literacy in this discipline.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline “Automatic Control Theory” 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)
GC-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 received 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	GC-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 received from various sources in order to effectively use the received information to solve problems; GC-12.2 Evaluates information, its reliability, builds logical conclusions based on incoming information and data;
GPC -10	Able to develop (based on current standards) technical documentation (including in electronic form) for routine maintenance of systems and controls, automation and management	GPC -10.1 Knows the current standards for the development of technical documentation for routine maintenance of systems and controls, automation and management; GPC -10.2 Knows the basic approaches to the development of technical documentation (including in electronic form) for routine maintenance of systems and controls, automation and management; GPC -10.3 Has the skills to develop (based on current standards) technical documentation (including in electronic form) for routine maintenance of systems and controls, automation and management;
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;

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
		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;
GPC -5	Able to solve problems of development of science, technology and technology in the field of management in technical systems, taking into account legal regulation in the field of intellectual property	GPC-5.1 Knows the theoretical foundations of digital technologies, the basics of modeling objects of professional activity, the basics of data analysis and information presentation; GPC-5.2 Able to solve problems of professional activity using existing methods of modeling, data analysis, and presentation of information; GPC -5.3 Has the skills to develop algorithms and computer programs suitable for practical use;
GPC-6	Able to develop and use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical application in the field of his professional activity	GPC-6.1 Knows basic algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical use in the field of their professional activities; GPC -6.2 Can use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical use in the field of their professional activities; GPC-6.3 Confidently masters algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical application in the field of his professional activity;
GPC -7	Able to make the necessary calculations of individual blocks and devices of monitoring, automation and control systems, select standard automation, measuring and computer equipment when designing automation and control systems	GPC -7.1 Knows the procedure for making the necessary calculations of individual blocks and devices of control, automation and control systems, selecting standard automation, measuring and computer equipment when designing automation and control systems; GPC - 7.2 Able to make the necessary calculations of individual blocks and devices of control, automation and control systems, select standard automation, measuring and computer equipment when designing automation and control systems; GPC -7.3 Possesses technologies for carrying out calculations of individual blocks and devices of monitoring, automation and control systems, selecting standard means of automation, measuring and computer equipment when designing automation and control systems;
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 " Automatic Control Theory " 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 “Automatic Control Theory”.

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***
GC-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 received 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	Analysis of Geoinformation Data; *Fundamentals of information security and cyber resilience***; *Fundamentals of information security and cyber resilience***;	Optimal Control Methods; Technological Training; Undergraduate practice / Pre-graduate practice;
GPC -2	Able to formulate tasks of professional activity based on knowledge, specialized sections of mathematical and natural science disciplines (modules)	Algebra and Geometry; Analysis of Geoinformation Data; Mathematical analysis; Space Flight Mechanics;	Technological Training; Undergraduate practice / Pre-graduate practice; Equations of mathematical physics; Space Flight Mechanics;
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; Equations of mathematical physics; Optimal Control Methods; Technological Training; Undergraduate practice / Pre-graduate practice;
GPC -5	Able to solve problems of development of science, technology and technology in the field of management in technical systems, taking into account legal regulation in the field of intellectual property	Theoretical Mechanics; Analysis of Geoinformation Data;	Technological Training; Undergraduate practice / Pre-graduate practice;
GPC -6	Able to develop and use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for	Computer Science and Programming; Space Flight Mechanics;	Space Flight Mechanics; Undergraduate practice / Pre-graduate practice;

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
	practical application in the field of his professional activity		
GPC -7	Able to make the necessary calculations of individual blocks and devices of monitoring, automation and control systems, select standard automation, measuring and computer equipment when designing automation and control systems		Undergraduate practice / Pre-graduate practice;
GPC -10	Able to develop (based on current standards) technical documentation (including in electronic form) for routine maintenance of systems and controls, automation and management		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; Analysis of Geoinformation Data; Computer Science and Programming; *Discrete mathematics***; *Discrete Math***;	Space Flight Mechanics; *Virtual and Augmented Reality Technology***; Technological Training; Undergraduate practice / Pre-graduate practice; *Virtual and augmented reality technologies***; Optimal Control Methods;

* - 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 "Automatic Control Theory" discipline is "9" 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	**6**
Contact work, ac.ch.	*144*		*72*	*72*
Lectures (LK)	72		36	36
Laboratory work (LR)	72		36	36
Practical/seminar sessions (SZ)	0		0	0
Independent work of students, ac.ch.	*135*		*18*	*117*
Control (exam/test with assessment), academic degree.	*45*		*18*	*27*
Total labor intensity of the discipline	**ac.ch.**	***324***	*108*	*216*
	credit units	***9***	*3*	*6*

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	Mathematical models and dynamic characteristics of linear stationary automatic control systems	1.1	Introduction. Apparatus of automatic control theory. Concepts: optimization, regulation, correction.	LK, LR
		1.2	General block diagram of self-propelled guns.	LK, LR
		1.3	Classification of ATS, including static and astatic.	LK, LR
		1.4	Obtaining mathematical models. Methodology for composing "input-output" equations. Input signals.	LK, LR
		1.5	Linearization of ACS equations. Superposition principle.	LK, LR
		1.6	Fourier transform. The concept of frequency response. Using frequency characteristics to determine the ATS response. Experimental determination.	LK, LR
		1.7	Laplace transform. Properties of the Laplace transform.	LK, LR
		1.8	The concept of transfer function. The concept of LAH. Relationship between frequency response and PF (“s”, “jw”, “p”).	LK, LR
		1.9	Typical structural units of the ATS. Example of output of PF of an aperiodic link	LK, LR
		1.10	Structural transformations of LSS circuits. Examples. Types of PF (closed, by mistake).	LK, LR
		1.11	Oscillatory link - properties. General table of properties of typical PFs.	LK, LR
		1.12	Construction of frequency characteristics, linear characteristics of connections of typical structural links.	LK, LR
		1.13	Duhamel integral. Connection of IPF with ChH and PF.	LK, LR
		1.14	Description of ACS in state space. Transition matrix, properties. Canonical forms	LK, LR
Section 2	Stability of linear systems	2.1	The concept of ATS stability. Necessary and sufficient condition for stability. Properties. Principle of argument.	LK, LR
		2.2	Frequency stability criteria. Mikhailov criterion. Nyquist-Mikhailov criterion.	LK, LR
		2.3	Modification of the Nyquist-Mikhailov criterion for astatic systems.	LK, LR
		2.4	Limits of applicability of evaluation methods using frequency criteria.	LK, LR
		2.5	Stability margin.	LK, LR
		2.6	Analytical stability criteria: Hurwitz, Routh, Zubov criterion	LK, LR
		2.7	Limits of applicability of assessment methods using analytical criteria.	LK, LR
		2.8	Influence of ACS parameters on stability: D-partition, root hodograph.	LK, LR
Section 3	Quality of automatic control systems	3.1	The concept of ATS quality. Primary quality indicators.	LK, LR
		3.2	Frequency and integral methods of quality assessment.	LK, LR
		3.3	Relationship between frequency characteristics and transition function.	LK, LR

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
		3.4	The ability to process signals as an assessment of the quality of the automatic control system. Error rates. Methods for calculating error coefficients. The influence of astatism on error coefficients and steady-state error.	LK, LR
Section 4	Correction of automatic control systems	4.1	Synthesis of ATS. Basics of synthesis.	LK, LR
		4.2	Types of ATS synthesis (structural, parametric).	LK, LR
		4.3	Approaches to correction of SAD.	LK, LR
		4.4	Solodovnikov's method of desired LAX. Synthesis algorithm, connection between frequency response and primary quality indicators for minimum phase links.	LK, LR
		4.5	PID controller. Typical correction links.	LK, LR
		4.6	Sensitivity theory. The concept of invariance.	LK, LR
Section 5	Mathematical models of nonlinear deterministic systems	5.1	The concept of nonlinear systems. Typical block diagram of a nonlinear system. Types of nonlinear elements.	LK, LR
		5.2	The concept of a phase plane. Construction of phase diagrams, fitting method.	LK, LR
		5.3	Construction of switching lines. Sliding mode. Isoclin method. Effect of feedback on switching lines in a relay system.	LK, LR
		5.4	Imaginary switching lines, construction rule. Accounting for pure delay.	LK, LR
		5.5	The concept of self-oscillations, estimation of parameters of self-oscillations.	LK, LR
		5.6	Harmonic linearization. Fourier series. An example of the passage of signals through a nonlinear element. Filter hypothesis.	LK, LR
		5.7	Derivation of the linearization equation. Calculation of linearization coefficients using an example.	LK, LR
Section 6	Stability of nonlinear systems	6.1	The concept of stability of nonlinear systems. Special modes of motion of nonlinear systems.	LK, LR
		6.2	Methods for assessing the stability of a cycle of self-oscillations: algebraic, graphical.	LK, LR
		6.3	Lamerey diagrams. Checking the self-oscillation cycle for stability.	LK, LR
		6.4	Methods for assessing the stability of self-oscillations: using Mikhailov and Nyquist-Mikhailov frequency criteria. Analogies with the stability of linear systems.	LK, LR
		6.5	Phase boundary of stability. Construction algorithm.	LK, LR
		6.6	Forced motion of nonlinear systems under harmonic influence. Offset function. Extension of the technique to search for forced motion of an arbitrary deterministic signal.	LK, LR
		6.7	General approaches to assessing the stability of systems. Lyapunov stability. The first is Lyapunov's method. The concept of stability in the large, in the small, asymptotic stability.	LK, LR
		6.8	Lyapunov equation. Stability theorem and instability theorem.	LK, LR
		6.9	Criteria for hyperstability (absolute stability). Frequency criterion V.M. Popova.	LK, LR
Section 7		7.1	The concept of random variables. Application of basic characteristics in ATS research problems:	LK, LR

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
			mathematical expectation, dispersion, spectral density, correlation.	
	Study of random processes in automatic control systems	7.2	Properties of characteristics of random variables, the concept of a “white noise” signal.	LK, LR
		7.3	Passage of a random signal through a linear stationary automatic control system. Derivation of the relation equation for spectral densities.	LK, LR
		7.4	Mathematical models of stochastic ACS in state space. Dispersion equations.	LK, LR
		7.5	Forming filter. Application examples.	LK, LR
		7.6	Methods for studying nonlinear ACS under random influences. Approaches to statistical linearization.	LK, LR
		7.7	Comparison of statistical linearization methods. Exelby, Buton (Kazakov), Pupkov.	LK, LR
Section 8	Synthesis of automatic control systems. Optimization.	8.1	Modal control. Methods for assigning roots.	LK, LR
		8.2	Observing devices.	LK, LR
		8.3	Methods for optimizing automatic control systems. The concept of quality functionality.	LK, LR
		8.4	Classical calculus of variations. Application of Lagrange equations for optimization.	LK, LR
		8.5	Pontryagin's maximum principle.	LK, LR
		8.6	Application of approaches for fixed and non-fixed control time. Transversality equation.	LK, LR
		8.7	Example of control optimization (Brachistochrone).	LK, LR
		8.8	Dynamic programming method. Hamilton-Jacobi-Bellman equation.	LK, LR
		8.9	Stochastic optimization methods. Wiener's problem. Kalman filter. The principle of separability.	LK, LR
		8.10	AKOR problem (analytical design of optimal controllers).	LK, LR
Section 9	Research of discrete automatic control systems	9.1	Discrete self-propelled guns. Quantization types: quantization by level, by value	LK, LR
		9.2	State space and models of continuous-discrete systems.	LK, LR
		9.3	Typical units of discrete self-propelled guns. The influence of the extrapolator. Comparison of response to typical impacts of continuous and discrete systems.	LK, LR
		9.4	Features of mathematical modeling of discrete systems. Difference between pulse and discrete systems.	LK, LR
		9.5	Kotelnikov's theorem. Frequency transposition effect.	LK, LR
		9.6	Transfer function of discrete systems.	LK, LR
		9.7	Direct and inverse Z-transform.	LK, LR
		9.8	Direct and inverse w-transform.	LK, LR
		9.9	Application of methods for studying linear stationary continuous systems for the case of discrete automatic control systems: stability assessment, correction, optimization.	LK, LR
Section 10	Non-stationary systems, general information.	10.1	Non-stationary automatic control systems. Description methods, approaches to research.	LK, LR
		10.2	Construction of dynamic characteristics of non-stationary systems	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.	
Laboratory	An auditorium for conducting laboratory work, individual consultations, ongoing monitoring and intermediate certification, equipped with a set of specialized furniture and equipment.	Personal computer with MATLAB software installed (with Simulink package), Control Toolbox package
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.	Personal computer with MATLAB software installed (with Simulink package) Control Toolbox package
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. Methods of classical and modern theory of automatic control: Textbook in 5 volumes / Ed. ed. K.A. Pupkova. - 2nd ed., revised. and additional - M.: Publishing house of MSTU, 2004. - 656 p.

2. Pupkov Konstantin Alexandrovich. Theory of nonlinear automatic control systems: Textbook for universities. - Anniversary edition. - M.: Publishing house RUDN, 2009. - 258 p.

3. Andrievsky B.R., Fradkov A.L. Selected chapters of automatic control theory with examples in languageMATLAB. - St. Petersburg: Nauka, 1999. - 475 p.

4. Solodovnikov Vladimir Viktorovich. Theory of automatic control of technical systems: Textbook / V.V.Solodovnikov, V.N.Plotnikov, A.V.Yakovlev. - M.: Publishing house of MSTU im.N.E. Bauman, 1993. - 492 p.

Additional literature:

1. Pupkov Konstantin Alexandrovich. Modern methods, models and algorithms of intelligent systems: Textbook. - M.: IPK RUDN, 2008. - 154 p.

2. Pupkov Konstantin Alexandrovich. Statistical methods of analysis, synthesis and identification of nonlinear automatic control systems: Textbook for universities / K. A. Pupkov,

N. D. Egupov, A. I. Trofimov; Ed. N. D. Egupova. - M.: Publishing house of MSTU im. N.E. Bauman, 1998. - 562 p.

3. Nikulchev E.V. Workshop on environmental control theoryMATLAB: Tutorial. - M.: MGAPI, 2002. - 88 p.

4. Besekersky Viktor Antonovich. Theory of automatic control systems. - M.: Nauka, 1966. - 992 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 "Theory of Automatic Control".

* - 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"Automatic Control Theory" is 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		Andrikov Dmitry Anatolievich
Position,	*Signature*	*Last name I.O.*

HEAD OF BUP:

Head of the department		Razumny Yuri Nikolaevich
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HEAD OF OP VO:

Professor		Razumny Yuri Nikolaevich
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