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

AUTOMATIC CONTROL THEORY
(name of discipline/module)

Recommended for the field of study/specialty:

27.03.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the field of study/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)

2026

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Automatic Control Theory" is part of the bachelor's program "Data Science and Space Systems" in the 27.03.04 "Control in Technical Systems" program and is studied in semesters 5 and 6 of the third year. The course is offered by the Department of Mechanics and Control Processes. It consists of 10 sections and 76 topics and focuses on the fundamental principles of mathematical models and dynamic characteristics of linear stationary automatic control systems, the stability of linear systems, the quality of automatic control systems, corrections to automatic control systems, mathematical models of nonlinear deterministic systems, the stability of nonlinear systems, the study of random processes in automatic control systems, the synthesis of automatic control systems and optimization, the study of discrete automatic control systems, nonstationary systems, general information, analysis of basic methods for solving typical problems, and an introduction to 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 activity, and to improve the overall level of literacy of students in this discipline.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline "Automatic Control Theory " 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 Competency Achievement (within this discipline)
UC-12	Able to search for relevant sources of information and data, perceive, analyze, memorize, and transmit information using digital tools, as well as algorithms when working with data obtained from various sources in order to effectively use the information obtained to solve problems; evaluate information, its reliability, and draw 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 with the help of algorithms when working with data obtained from various sources in order to effectively use the information received to solve problems; UC-12.2 Conducts an assessment of information, its reliability, builds logical conclusions based on incoming information and data;
GPC-10	Capable of developing (based on current standards) technical documentation (including in electronic form) for routine maintenance of control, automation and management systems and equipment	GPC-10.1 Knows the current standards for the development of technical documentation for routine maintenance of control, automation and management systems and equipment; GPC-10.2 Knows the basic approaches to the development of technical documentation (including in electronic form) for routine maintenance of control, automation and management systems and equipment; GPC-10.3 Possesses the skills to develop (based on current standards) technical documentation (including in electronic form) for routine maintenance of control, automation and management systems and equipment;
GPC-2	Able to formulate objectives for professional activity based on knowledge of specialized sections of mathematical and natural science disciplines (modules)	GPC-2.1 Has a command of 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 skills in developing and implementing algorithms for solving applied problems in the field of professional

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
		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, 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-5	Capable of solving problems of development of science, engineering and technology in the field of management in technical systems, taking into account the legal framework 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 presentation of information; GPC-5.2 Able to solve problems of professional activity using existing methods of modeling, data analysis, and information presentation; GPC-5.3 Possesses skills in developing algorithms and computer programs suitable for practical application;
GPC-6	Capable of developing and using 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 the basic 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-6.2 Able to apply 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-6.3 Confidently uses 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	Capable of performing the necessary calculations for individual units and devices of control, automation and management systems, and selecting standard automation, measuring and computing equipment when designing automation and control systems	GPC-7.1 Knows the procedure for performing the necessary calculations for individual blocks and devices of control, automation and management systems, and selects standard automation, measuring and computing equipment when designing automation and control systems; GPC-7.2 Can perform the necessary calculations for individual units and devices of control, automation and management systems, select standard automation, measuring and computing equipment when designing automation and control systems; GPC-7.3 Proficient in technologies for performing calculations of individual units and devices of control, automation and management systems, selecting standard automation, measuring and computing 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 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;

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

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 higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Theory of Automatic 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, practical training*	Subsequent disciplines/modules, practices*
UC-12	Able to search for relevant sources of information and data, perceive, analyze, memorize, and transmit information using digital tools, as well as algorithms when working with data obtained from various sources in order to effectively use the information obtained to solve problems; evaluate information, its reliability, and draw 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 Training; Research Work;
GPC-6	Capable of developing and using 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	Computer Science and Programming; Space Flight Mechanics; Introduction to Computing Science;	Undergraduate Training; Space Flight Mechanics;
GPC-2	Able to formulate objectives for professional activity based on knowledge of specialized sections of mathematical and natural science disciplines (modules)	Algebra and Geometry; Analysis of Geoinformation Data; Mathematical analysis; Space Flight Mechanics;	Equations of mathematical physics; Space Flight Mechanics; Technological Training; Undergraduate Training; Research Work;
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;	Technological Training; Undergraduate Training; Space Flight Mechanics; Equations of mathematical physics; Optimal Control Methods;
GPC-5	Capable of solving problems of development of science, engineering and technology in the field of management in technical systems, taking into account the legal framework in the field of intellec-	Theoretical Mechanics; Analysis of Geoinformation Data; Fundamentals of Artificial Intelligence;	Technological Training; Undergraduate Training;

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
	tual property		
GPC-7	Capable of performing the necessary calculations for individual units and devices of control, automation and management systems, and selecting standard automation, measuring and computing equipment when designing automation and control systems		Undergraduate Training;
GPC-10	Capable of developing (based on current standards) technical documentation (including in electronic form) for routine maintenance of control, automation and management systems and equipment		Technological Training; Undergraduate 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	Space Flight Mechanics; Computer Science and Programming; *Discrete Mathematics***; *Discrete Mathematics***; Analysis of Geoinformation Data; Introduction to Computing Science;	Technological Training; Undergraduate Training; Space Flight Mechanics; *Virtual and Augmented Reality Technology***; *Virtual and augmented reality technologies***; Optimal Control Methods;

* - filled in accordance with the competency matrix and the SUP EP HE
** - elective courses/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF EDUCATIONAL WORK

The total workload of the course "Automatic Control Theory " 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,** academic hours		**Semester(s)**	
			5	**6**
Contact work, academic hours	*144*		*72*	*72*
Lectures (LC)	72		36	36
Laboratory work (LW)	72		36	36
Practical/seminar classes (SC)	0		0	0
Independent work of students, academic hours	*171*		*54*	*117*
Control (exam/test with assessment), academic hours	*45*		*18*	*27*
Total complexity of the discipline	**academic hours**	***360***	*144*	*216*
	credit	***10***	*4*	*6*

The total workload of the course "Automatic Control Theory " is 10 credit units.

Table 4.2. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,** academic hours		**Semester(s)**	
			5	**6**
Contact work, academic hours	*144*		*72*	*72*
Lectures (LC)	72		36	36
Laboratory work (LW)	72		36	36
Practical/seminar classes (SC)	0		0	0
Independent work of students, academic hours	*171*		*54*	*117*
Control (exam/test with assessment), academic hours	*45*		*18*	*27*
Total complexity of the discipline	**academic hours**	***360***	*144*	*216*
	credit	***10***	*4*	*6*

The total workload of the course "Automatic Control Theory " is 10 credit units.

Table 4.3. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,** academic hours		**Semester(s)**	
			5	**6**
Contact work, academic hours	*144*		*72*	*72*
Lectures (LC)	72		36	36
Laboratory work (LW)	72		36	36
Practical/seminar classes (SC)	0		0	0
Independent work of students, academic hours	*171*		*54*	*117*
Control (exam/test with assessment), academic hours	*45*		*18*	*27*
Total complexity of the discipline	**academic hours**	***360***	*144*	*216*
	credit	***10***	*4*	*6*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of academic work

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 1	Mathematical models and dynamic characteristics of linear stationary automatic control systems	1.1	Introduction. Theory of automatic control. Concepts: optimization, regulation, correction.	The subject and objectives of automatic control theory. Key concepts: optimization as ensuring the best control quality; regulation as maintaining a given regime; correction as a targeted change in the properties of a system to improve its performance.	LC, LW
		1.2	General structural diagram of the ACS.	Basic elements: control object, control device, feedback sensors, comparison device. Concepts of reference action, controlled signal, control error, and disturbance. Closed-loop and open-loop systems.	LC, LW
		1.3	Classification of SAR, including static and astatic.	Classification by purpose, by type of control action, by the nature of the change in the reference signal. Static systems: the presence of an error in steady-state mode with a constant action. Astatic systems: the absence of a steady-state error with a constant action (integrators in the loop).	LC, LW
		1.4	Deriving mathematical models. Methods for constructing input-output equations. Input signals.	Constructing a mathematical description based on physical laws. Dynamic equation in input-output form (the relationship between the control and output signals). Typical input signals: step, pulse, harmonic, and ramp.	LC, LW
		1.5	Linearization of the SAR equations. Superposition principle.	Linearization of nonlinear equations in the vicinity of the operating point: Taylor series expansion and discarding nonlinear terms. The principle of superposition (independence of signal action) as a consequence of linearity. The scope of applicability of linearized models.	LC, LW
		1.6	Fourier transform. Concept of frequency response. Using frequency responses to determine the response of the automatic control system. Experimental determination.	The Fourier transform as a transition from a time-domain representation of a signal to a frequency-domain representation. Frequency response as a system's response to a harmonic signal. Using frequency responses to calculate steady-state response. Experimental recording of frequency responses.	LC, LW
		1.7	Laplace transform. Properties of the Laplace transform.	Definition of the Laplace transform. Transition from functions of time to functions of a complex variable. Key properties: linearity, differentiation of the original, integration of the original, delay theorem, convolution theorem.	LC, LW
		1.8	The concept of a transfer function. The concept of a linear axicon. The relationship between the frequency response and the phase	Transfer function as the ratio of the output and input signal images under zero initial conditions. Logarithmic amplitude-frequency characteristics: plotting on a logarithmic scale. The relationship	LC, LW

Section number	Name of the discipline section		Topic Title	Topic Contents	Type of academic work*
			function ("s", "jw", "p").	between frequency response and transfer function.	
		1.9	Typical structural links of the automatic control system. Example of the output of the PF of an aperiodic link	Basic links: proportional (amplifying), integrating, differentiating, aperiodic (inertial), and oscillatory. Deriving the transfer function of an aperiodic link from a first-order differential equation.	LC, LW
		1.10	Structural transformations of LSS circuits. Examples. Types of PF (closed, by error).	Rules for transforming structural diagrams: series, parallel, and feedback connections. Closed-loop transfer function. Error transfer function (error-to-controller relationship).	LC, LW
		1.11	Oscillatory element properties. General table of properties of typical PFs.	Oscillatory link characteristics: parameters (damping coefficient, natural frequency). Time and frequency characteristics. Summary table of typical link properties: transfer functions, transient functions, frequency characteristics.	LC, LW
		1.12	Construction of frequency characteristics, linear characteristics of connections of typical structural links.	Plotting frequency responses for series, parallel, and feedback connections. Plotting logarithmic amplitude-frequency responses as the sum of the characteristics of individual links. Asymptotic approximations.	LC, LW
		1.13	Duhamel integral. Relationship of the IPF with the frequency response and the PF.	The Duhamel integral (convolution integral) as a method for calculating the system's response to an arbitrary stimulus. The impulse response function (weighting function) as a response to a single impulse. The relationship of the impulse response function to the transfer function and frequency response.	LC, LW
		1.14	Description of the ACS in state space. Transition matrix, properties. Canonical forms,	Representation of a system as a set of first-order differential equations. State vector, system matrices, input, and output. Transition matrix (exponential matrix) and its properties. Controlled, observable, and Jordan canonical forms.	LC, LW
Section 2	Stability of linear systems	2.1	The concept of stability of the SAR. Necessary and sufficient conditions for stability. Properties. The argument principle.	Definition of Lyapunov stability: a bounded response to a limited stimulus. Necessary and sufficient condition: all poles of the transfer function must have negative real parts. Argument principle (change in the argument of the characteristic polynomial as it moves along the contour).	LC, LW
		2.2	Frequency stability criteria. Mikhailov criterion. Nyquist-Mikhailov criterion.	Mikhailov criterion: constructing the hodograph of the characteristic polynomial; stability if the hodograph sequentially traverses a given number of quadrants. Nyquist-Mikhailov criterion: assessing the stability of a closed-loop system based on the frequency response of an open-loop system.	LC, LW
		2.3	Modification of the Nyquist-Mikhailov criterion for astatic systems.	Application of the Nyquist criterion to systems with integrators (astatic systems). Rule for complementing the hodograph with an	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				infinite-radius arc. Determining stability for systems with astatic behavior of varying degrees.	
		2.4	Limits of applicability of assessment methods using frequency criteria.	Limitations of frequency criteria: applicability only to linear time-invariant systems; minimum-phase requirement for simplified formulations; difficulty of application in the presence of delay.	LC, LW
		2.5	Safety margin.	The concept of stability margin as a quantitative measure of a system's distance from the stability boundary. Amplitude margin and phase margin. Definition using logarithmic frequency characteristics. Recommended margin values.	LC, LW
		2.6	Analytical criteria of stability: Hurwitz, Routh, Zubov criteria	Hurwitz criterion: testing the positivity of all principal diagonal minors of the Hurwitz matrix. Routh criterion: constructing a Routh table and checking the signs of the first column. Zubov criterion for discrete systems.	LC, LW
		2.7	Limits of applicability of assessment methods using analytical criteria.	Applicability to low-order systems (algebraic criteria become cumbersome). Requirement of a characteristic polynomial. Inapplicability to systems with delay.	LC, LW
		2.8	The influence of the SAR parameters on stability: D-partition, root hodograph.	D-partition: a method for constructing stability regions in parameter space. Root locus: the trajectories of the poles of a closed-loop system as a parameter (gain) changes. Using the root locus for parameter selection.	LC, LW
Section 3	Quality of automatic control systems	3.1	The concept of quality of the SAR. Primary quality indicators.	Definition of quality as a set of characteristics of a transient process. Primary (direct) indicators: regulation time, overshoot, oscillation, number of overshoots, rise time, steady-state error.	LC, LW
		3.2	Frequency and integral methods of quality assessment.	Frequency methods: the relationship of quality indicators with the type of frequency characteristics (oscillation index, resonance peak, cutoff frequency). Integral methods: linear and quadratic integral quality assessments (integral of the error modulus, integral of the squared error).	LC, LW
		3.3	Relationship of frequency characteristics with the transition function.	The relationship between time and frequency descriptions through Fourier and Laplace integrals. The influence of the low-frequency, mid-frequency, and high-frequency regions of the frequency response on the type of transient process.	LC, LW
		3.4	Signal processing capability as an assessment of ACS quality. Error rates. Methods for calculating error rates. The influence of astaticity on error rates and steady-state error.	Error coefficients as expansions of the error transfer function in powers of a complex variable. Calculating error coefficients using derivatives of the transfer function. The effect of the order of astatism on the steady-state error under polynomial influences.	LC, LW

Section number	Name of the discipline section		Topic Title	Topic Contents	Type of academic work*
Section 4	Correction of automatic control systems	4.1	Synthesis of SAR. Basics of synthesis.	The task of synthesizing (designing) a system with specified performance indicators. Selecting the controller structure and parameters. Balancing the requirements of stability, accuracy, and transient response quality.	LC, LW
		4.2	Types of SAR synthesis (structural, parametric).	Structural synthesis: selection of the system design principle, controller type, and location of the control units. Parametric synthesis: calculation of the numerical values of the controller parameters.	LC, LW
		4.3	Approaches to the correction of SAD.	Correction by sequential links, parallel links, and feedback loops. Local and global feedback loops. Advantages and disadvantages of different approaches.	LC, LW
		4.4	Solodovnikov's method of desired LAC. Synthesis algorithm, relationship between frequency response and primary quality indicators for minimum-phase links.	Construction of the desired logarithmic amplitude-frequency response that ensures the required performance indicators. Algorithm: determination of the low-frequency, mid-frequency, and high-frequency regions. Relationship of cutoff frequency with control time and overshoot.	LC, LW
		4.5	PID controller. Typical correction links.	PID controller structure: proportional, integrating, and differentiating components. The influence of each component on the system's properties. Typical control elements: boost, integrating-boosting, and inertial.	LC, LW
		4.6	Sensitivity theory. The concept of invariance.	System sensitivity to parameter changes. Sensitivity functions. Invariance as a property of output variable independence from disturbances. Principles of combined control to ensure invariance.	LC, LW
Section 5	Mathematical models of nonlinear deterministic systems	5.1	The concept of nonlinear systems. Typical structural diagram of a nonlinear system. Types of nonlinear elements.	Nonlinear systems differ from linear systems in that they violate the superposition principle, can undergo self-oscillation, and their properties depend on signal amplitude. Typical nonlinearities include relay nonlinearities, dead band, saturation, backlash, and dry friction.	LC, LW
		5.2	The concept of a phase plane. Construction of phase diagrams, the fitting method.	Phase plane for second-order systems: coordinate and its derivative. Phase trajectories. The fitting method: analytical solution on sections and stitching of solutions during switching.	LC, LW
		5.3	Construction of switching lines. Sliding mode. Isocline method. Effect of feedback on switching lines in a relay system.	Switching lines as the geometric locus of system structure change points. Sliding mode: movement along the switching line. The isocline method for approximate construction of phase trajectories. The effect of feedback on the slope of switching lines.	LC, LW
		5.4	Imaginary switching lines, construction rule.	The concept of minimum (imaginary) switching lines for systems	LC, LW

Section number	Name of the discipline section		Topic Title	Topic Contents	Type of academic work*
			Accounting for pure delay.	with delay. Rules for graphical construction. The influence of pure delay on the phase portrait and stability.	
		5.5	The concept of self-oscillations, assessment of self-oscillation parameters.	Self-oscillations as undamped periodic modes in nonlinear systems. Self-oscillation parameters: amplitude and frequency. Conditions for the occurrence of self-oscillations.	LC, LW
		5.6	Harmonic linearization. Fourier series. Example of signal passage through a nonlinear element. Filter hypothesis.	Harmonic linearization: replacing a nonlinear element with an equivalent amplitude-dependent linear element. Fourier series expansion of the output signal of the nonlinear element with a harmonic input. Filter hypothesis: the assumption that the linear component suppresses higher harmonics.	LC, LW
		5.7	Derivation of the linearization equation. Calculation of the linearization coefficients using an example.	Obtaining harmonic linearization coefficients for typical nonlinearities. Calculating coefficients for an ideal relay, a relay with a dead zone, and a relay with a saturation zone. Calculation example.	LC, LW
Section 6	Stability of nonlinear systems	6.1	The concept of stability of nonlinear systems. Special modes of motion of nonlinear systems.	Stability features of nonlinear systems: dependence on initial conditions and disturbance amplitude. Special regimes: equilibrium positions, limit cycles (stable and unstable).	LC, LW
		6.2	Methods for assessing the stability of a self-oscillation cycle: algebraic, graphical.	Algebraic methods: analysis of the characteristic equation of a linearized system in the vicinity of a cycle. Graphical methods: use of the Mikhailov hodograph to assess the stability of a limit cycle.	LC, LW
		6.3	Lamerey diagrams. Testing the stability of a self-oscillating cycle.	Construction of Lamerey diagrams for discrete mappings (e.g., for relay systems). Determining the stability of a limit cycle based on the behavior of trajectories near the cycle.	LC, LW
		6.4	Methods for assessing the stability of self-oscillations: using the Mikhailov and Nyquist-Mikhailov frequency criteria. Analogies to the stability of linear systems.	Application of the Mikhailov criterion to a harmonically linearized system. Application of the Nyquist criterion to assess limit cycle stability based on the frequency response of the linear component and harmonic linearization coefficients.	LC, LW
		6.5	Phase boundary of stability. Construction algorithm.	The concept of a phase boundary of stability on the parameter plane. Construction algorithm: determining the conditions for the occurrence of self-oscillations with zero frequency or infinite amplitude.	LC, LW
		6.6	Forced motion of nonlinear systems under harmonic influence. Displacement function. Extension of the method to search for forced motion of an arbitrary deterministic signal.	Forced periodic modes in nonlinear systems under the influence of an external harmonic signal. Bias function for synchronization analysis. Generalization to arbitrary deterministic signals.	LC, LW
		6.7	General approaches to assessing system stability. Lyapunov stability. The first Lyapunov	Definitions of Lyapunov stability: stability with respect to initial conditions. The first Lyapunov method (linearization in the neigh-	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
			method. The concept of stability in the large, small, and asymptotic ranges.	borhood of the equilibrium position). Stability in the small (local) and large (global) dimensions. Asymptotic stability.	
		6.8	Lyapunov equation. Stability theorem and instability theorem.	The second Lyapunov method (direct method). Lyapunov function (definitely positive function). Lyapunov equation for linear systems. Lyapunov stability theorem (existence of a Lyapunov function with a negative derivative). Chetaev instability theorem.	LC, LW
		6.9	Criteria of hyperstability (absolute stability). V.M. Popov's frequency criterion.	Absolute stability: stability under any form of nonlinearity belonging to a given class (e.g., sector). Popov criterion: a graphical condition on the modified frequency response of the linear part.	LC, LW
Section 7	Study of random processes in automatic control systems	7.1	The concept of random variables. Application of key characteristics to SAR research problems: mathematical expectation, variance, spectral density, correlation.	Random influences in control systems. Mathematical expectation (mean value). Variance (measure of spread). Correlation function (relationship between process values at different points in time). Power spectral density (distribution of variance by frequency).	LC, LW
		7.2	Properties of characteristics of random variables, the concept of a "white noise" signal.	Properties of the correlation function and spectral density. White noise: a process with constant spectral density and a delta-shaped correlation function. Idealization and practical applications.	LC, LW
		7.3	Passage of a random signal through a linear stationary automatic control system. Derivation of the equation for the relationship between spectral densities.	Transformation of the correlation function and spectral density when passing through a linear system. Relationship: the output spectral density is equal to the square of the frequency response modulus multiplied by the input spectral density.	LC, LW
		7.4	Mathematical models of stochastic automatic control systems in state space. Dispersion equations.	Representation of stochastic systems in state space with the addition of random influences. Dispersion equations (equations for the covariance matrix of the state vector) are the Lyapunov equation for stochastic systems.	LC, LW
		7.5	Shaping filter. Application examples.	A shaping filter as a linear system transforming white noise into a random process with a given spectral density. Construction of shaping filters for typical correlation functions (exponential, bell-shaped).	LC, LW
		7.6	Methods for studying nonlinear automatic control systems with random influences. Approaches to statistical linearization.	Statistical linearization: replacement of a nonlinear element with an equivalent linear link, the parameters of which are selected from the condition of minimizing the approximation error according to probability characteristics.	LC, LW
		7.7	Comparison of statistical linearization methods. Exelby, Bouton (Kazakov), Pupkov.	Various approaches to statistical linearization: minimum error variance, least squares, and Kazakov and Pupkov methods. Comparison of accuracy and applicability.	LC, LW
Section 8	Synthesis of automatic con-	8.1	Modal control. Methods of root assignment.	Modal control: formulating a control law to ensure the desired	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
	trol systems. Optimization.			position of the poles of a closed-loop system. Methods for calculating modal controller coefficients (Ackermann's formula, method of undetermined coefficients).	
		8.2	Observation devices.	An observer as a dynamic system reconstructing a state vector from measured output variables. Observers of full and reduced order. The separability principle.	LC, LW
		8.3	Methods for optimizing automatic control systems. The concept of quality functionality.	Statement of the control optimization problem. Quality functional as a quantitative measure of control effectiveness. Examples of functionals: integral of the squared error, integral of the squared control signal, and energy functionals.	LC, LW
		8.4	Classical calculus of variations. Application of Lagrange's equations to optimization.	Problems of the calculus of variations in control theory. The Euler-Lagrange equation as a necessary condition for the extremum of a functional. Application to problems with fixed boundaries.	LC, LW
		8.5	Pontryagin's maximum principle.	Maximum principle for optimal control problems with control constraints. Hamiltonian function. Necessary optimality condition: maximization of the Hamiltonian function with respect to control.	LC, LW
		8.6	Application of approaches to fixed and non-fixed control time. Transversality equation.	Features of problems with fixed and free process completion times. Transversality equation for boundary conditions at the free ends of a trajectory.	LC, LW
		8.7	Example of control optimization (Brachistochrone).	The classical brachistochrone problem as an optimal control problem. Statement, derivation of optimality conditions, and solution.	LC, LW
		8.8	Dynamic programming method. Hamilton-Jacobi-Bellman equation.	Dynamic programming for continuous systems. Bellman's optimality principle. Hamilton-Jacobi-Bellman partial differential equation.	LC, LW
		8.9	Stochastic optimization methods. Wiener problem. Kalman filter. Separability principle.	Optimal linear filtering problem (Wiener). Kalman filter: a recurrent state estimation algorithm for linear stochastic systems. Separability principle for stochastic control problems: optimal control and optimal filtering are solved independently.	LC, LW
		8.10	The problem of AKOR (analytical design of optimal controllers).	Statement of the problem of analytical design of optimal controllers for linear systems with a quadratic performance functional. Solution via the Riccati equation. Linear-quadratic controller.	LC, LW
Section 9	Research of discrete automatic control systems	9.1	Discrete ACS. Quantization types: level-based, value-based	Discrete systems: signals are defined only at discrete moments in time. Time quantization (time discretization). Level quantization (amplitude quantization).	LC, LW
		9.2	State space and models of continuous-discrete systems.	Description of systems containing both continuous and discrete components (digital controllers, analog-to-digital converters).	LC, LW

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				Discretization of continuous models.	
		9.3	Typical links of discrete ACS. Effect of extrapolator. Comparison of the response of continuous and discrete systems to typical inputs.	Extrapolators (fixators) – discrete signal generators. Typical discrete components: discrete integrator, discrete aperiodic component. Comparison of transient processes in continuous and discrete systems.	LC, LW
		9.4	Features of mathematical modeling of discrete systems. Differences between pulse and discrete systems.	Pulse systems: time quantization with preservation of the value over the interval (pulse amplitude modulation). Purely discrete systems: signals are defined only at instants in time.	LC, LW
		9.5	Kotelnikov's theorem. Frequency transposition effect.	Conditions for reconstructing a continuous signal from its discrete samples: the sampling frequency must be no less than twice the maximum frequency in the signal spectrum. Aliasing and frequency transposition are possible.	LC, LW
		9.6	Transfer function of discrete systems.	Definition of a discrete transfer function as the ratio of the Z-images of the output and input signals. Transfer function of an open-loop and closed-loop discrete system.	LC, LW
		9.7	Direct and inverse Z-transform.	The Z-transform as an analogue of the Laplace transform for discrete signals. Definition of the direct and inverse Z-transforms. Table of basic Z-transforms.	LC, LW
		9.8	Direct and inverse w-transform.	Bilinear transform (w-transform): mapping the unit circle of the Z-plane onto the imaginary axis of the W-plane. Using the w-transform to apply frequency-domain stability criteria to discrete systems.	LC, LW
		9.9	Application of methods for studying linear stationary continuous systems for the case of discrete ACS: stability assessment, correction, optimization.	Stability criteria for discrete systems: the condition of the poles being located within the unit circle. The Schur-Kohn criterion. The Nyquist frequency criterion for discrete systems. Correction and optimization of discrete systems.	LC, LW
Section 10	Non-stationary systems, general information.	10.1	Non-stationary automatic control systems. Description methods, research approaches.	Nonstationary systems: system parameters depend on time. Description methods: differential equations with variable coefficients. Research approaches: frozen coefficient method (for slowly changing parameters), Lyapunov methods, numerical methods.	OK
		10.2	Construction of dynamic characteristics of non-stationary systems	Features of constructing time and frequency characteristics for non-stationary systems (dependence of characteristics on the moment of signal application). Transient functions for non-stationary systems. Impulse transient functions as functions of two variables.	OK

* - to be completed 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 for the discipline

Audience type	Equipment of the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	A lecture hall equipped with specialized furniture, a whiteboard (screen), and multimedia presentation equipment.	
Laboratory	A classroom for laboratory work, individual consultations, ongoing monitoring and midterm assessment, equipped with a set of specialized furniture and equipment.	A personal computer with installed MATLAB software (with the Simulink package), Control Toolbox package
Computer class	A computer room for conducting classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with personal computers (14 in total), a board (screen) and technical means for multimedia presentations.	A personal computer with installed MATLAB software (with the Simulink package) and the Control Toolbox package
For independent work	A classroom for independent student work (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the classroom for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. Methods of classical and modern theory of automatic control: Textbook in 5 volumes / Under the general editorship of K.A. Pupkov. - 2nd ed., revised and enlarged. - Moscow: Publishing house of Moscow State Technical University, 2004. - 656 p.

2. Pupkov Konstantin Aleksandrovich. Theory of nonlinear automatic control systems: Textbook for universities. - Anniversary edition. - M.: RUDN University Press, 2009. - 258 p.

3. Andrievsky B.R., Fradkov A.L. Selected chapters of automatic control theory with examples in MATLAB language. - 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 Bauman Moscow State Technical University, 1993. - 492 p.

Further reading:

1. Pupkov Konstantin Aleksandrovich. Modern methods, models and algorithms of intelligent systems: Study guide. - M.: IPC RUDN, 2008. - 154 p.

2. Pupkov Konstantin Aleksandrovich. 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. Egupov. - M.: Publishing house of Bauman Moscow State Technical University, 1998. - 562 p.

3. Nikulchev E.V. Practical training in control theory in the MATLAB environment: 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. RUDN University Electronic Library System and third-party electronic library systems to which university students have access based on concluded agreements
   - Electronic library system of RUDN - ELS RUDN http://lib.rudn.ru/MegaPro/Web
   - Electronic Library System "University Library Online" http://www.biblioclub.ru
   - EBS Yurayt http://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 regulatory documentation http://docs.cntd.ru/
   - Yandex search engine https://www.yandex.ru/
   - Google search engine https://www.google.ru/
   - SCOPUS abstract database 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 "Theory of automatic control".

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

DEVELOPERS:

Associate Professor		Andrikov Denis Anatolyevich
Position, DEPARTMENT	*Signature*	*Surname I.O.*
Associate Professor		Andrikov Dmitry Anatolyevich
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