Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
Perm National Research Polytechnic University

APPROVED BY
Pro-rector for Academic Affairs
_____ N.V. Lobov
"25" 11 2021

ACADEMIC COURSE WORKING PROGRAM

Academic course: Automatic Control Theory
(Name)

Form of education: Full-time studies
(Full-time /full-time - correspondence/correspondence)

Level of higher education: Bachelor's program
(Bachelor's program/specialist program/Master's program)

Workload in hours (in credits): 144 (4)
(Hours (CU))

Training program (degree): 15.03.06 Mechatronics and Robotics
(Code and denomination of degree)

Direction: Mechatronics and Robotics
(Title of curriculum)

Perm 2021

1. General Provisions

1.1. Goals and Objectives of the Course

The goal of the course is to master the specified disciplinary competencies in the development and research of automatic control systems; formation of a systematic approach to solving management problems; acquisition of skills necessary to perform research and design work on the creation and im

Discipline objectives:

- Studying the basic methods of mathematical description of objects and control systems; mastering the forms of presentation and transformation of models of control systems; study of the basic properties of automatic control systems and fundamental principles of control;
- Formation of skills to systematize information about objects and control systems; select the best method for mathematical description of the object and control systems; to select the optimal control law in systems;
- Formation of skills in analysis and synthesis of automatic control systems; work with standard hardware and software for modeling automatic control systems.

1.1. Prescribed Objects of the Course

Discipline objects:

- principles of building automatic control systems;
- mathematical methods for describing objects of control systems;
- methods of the theory of stability;
- methods of synthesis of ACS;
- applied software for analysis and synthesis of ACS

1.2. Starting Conditions

Unstipulated

2. Planned Results of the Course Training

Competence	Indicator's Index	Planned Results of the Course Training (to know, to be able, to master)	Indicator of Attaining Competence which the planned results of training are correlated with	Means of Assessment
GPC-4	**IA-1$_{GPC-4}$**	**To know** • basic approaches to the synthesis of linear ACS; • basic methods of synthesis of linear continuous ACS; • typical control laws; • basic software and hardware tools for modeling and research of ACS	**Knows** the rules of methods development for conducting research by working objects of mechatronics and robotics.	Exam

GPC-4	**IA-2$_{GPC-4}$**	**To be able to** • choose structures and schemes of automatic regulation and control, carry out parametric optimization regulating and controlling devices; • synthesize laws and algorithms for optimal control of objects; • analyze the quality of management; • to carry out simulation of ACS with using modern software and hardware.	**Is able to** make experiments and process research results.	Control work
GPC-4	**IA-3$_{GPC-4}$**	**To master the skills** of analysis and synthesis of linear, discrete and nonlinear ACS;	**Has mastered the skills** of processing the results of experiments on the base of modern information technologies and technical facilities.	Laboratory work presentation
RPC-2	**IA-1$_{RPC-2}$**	**To know** • basic principles and laws of functioning of automatic control systems; • dynamic and frequency characteristics of the ACS; • typical links of linear automatic control systems; • graphical methods for describing ACS using structural diagrams; • method for constructing the LAFC • mathematical description of the ACS in the state space; • basic provisions of the theory of stability; • algebraic and frequency stability criteria; • main indicators of ACS quality and methods for assessing the quality of ACS	**Knows** methods of calculating individual units and devices of mechatronic and robotic systems.	Exam

RPC-2	**IA-2$_{RPC-2}$**	**To be able to** • use the basic methods of analysis of ACS in the time and frequency domains; • to compose and transform the structural schemes of the ACS and the schemes of state variables; • build LACH of complex systems; • assess the stability of the ACS;	**Is able to** apply methods and tools for designing individual blocks and devices of mechatronic and robotic systems.	Control work
RPC-2	**IA-3$_{RPC-2}$**	**To master the skills** of research and modeling of linear, discrete and nonlinear ACS using standard software.	**Has mastered the skills** of using standard measuring and computing equipment in the design and calculations of individual blocks and devices of mechatronic and robotic systems.	Laboratory work presentation

3. Full time and forms of academic work

Form of academic work	Hours in all	Distribution in hours according to semesters
		Number of semester
		5
1. Holdingclasses (including results monitoring) intheform: 1.1.Contactclasswork, including:	66	66
- lectures (L)	36	36
- laboratory work (LW)	16	16
- practice, seminars and/other seminar -typework (PW)	10	10
- control of self-work (CSW)	4	4
- test		
1.2. Students' self-work (SSW)	42	42
2. Intermediate attestation		
Exam	36	36
Grading test		
Test (Credit)		
Course Project (CP)		
Course Work (CW)		
Total workload in hours	**144**	**144**

4. Course contents

Course units with brief contents	Full time of classroom activity in hours according to the forms			Full time of extracurricular work in hours according to the forms
	L	LW	PW	SSW
5th semester				
Basic concepts and definitions of the theory automatic control.	2	0	2	2
Topic 1. Basic concepts and definitions. Goals and objectives of the course of the theory of automatic control, the content of the discipline. Communication of TAU with other disciplines. The history of the development of ACS and TAU. The role of Russian and Russian scientists in the development of TAU. TAU and cybernetics. Role of the course in the formation of a modern engineer. The role of TAU in solving urgent problems of scientific and technical progress. The essence of management. The concepts of automatic regulation, automatic control and automated control. Basic terms and definitions of the theory of automatic control: control object, regulator, automatic control system, links, functional diagram of the ACS, influences: master and control, controlled variable, disturbances: load and interference, control error, statics and dynamics of ACS. Behavior of objects and control systems; information and management principles; examples of SU with technical, economic and organizational objects. Topic 2. Classification of automatic management. Classification of automatic control systems on the dynamics of processes occurring in the system and in the object of management. Linear and nonlinear ACS. Continuous and discrete systems. Deterministic and stochastic systems. Fundamental principles of management. Classification by function of the manager impact. Stabilization systems, tracking systems, software control systems, optimal and adaptive systems. Examples. Classification of ACS control principle. Systems deviation control, control systems perturbation, combined systems. Principle regulation by deviation. Closed and open loop systems. Systems concepts continuous, pulse and relay control. Feedback concepts (rigid, flexible, negative and positive connections). Examples.				

Static and astatic systems and their properties in stationary mode. Examples. One-dimensional and multidimensional systems. The typical structure of the ACS and its main elements (control object, sensitive element, control device, comparison element, regulating body). Direct and indirect control systems. Stationary and non-stationary automatic control systems. Lumped and distributed parameters.				
Mathematical description of linear continuous automatic control systems.	10	4	4	10
Topic 3. Classical mathematical description SPG. Methods for mathematical modeling of links and automatic control systems. Description dynamics and statics of processes. Linear continuous models. Input-output models. Differential equations and their linearization. Types of typical input signals. Dynamic temporal characteristics: transient characteristic and impulse transient characteristic. Laplace transform. Concept transfer function. Frequency characteristics: amplitude-phase characteristic (AFC), amplitude-frequency characteristic (AFC), phase-frequency characteristic (PFC), logarithmic amplitude-frequency characteristic (LAPH). The physical meaning of frequency characteristics. Topic 4. Typical links of ACS. Typical links: inertialess (amplifying), aperiodic link, oscillating link, ideal and real integrating links, ideal and real differentiating links, forcing links, pure retardation link. Time and frequency characteristics, transfer function of typical links. The concept of mini-phase links. Construction method LAPH. Topic 5. Graphic presentation of ACS. The concept of the structural diagram of the ACS. Calculation of the transfer function for different connections of links (serial, parallel, with feedback). Rules for converting structural diagrams. The concept of graphs. Representation of ACS in the form of a directed graph. Determination of transfer functions by Mason's formula. Topic 6. State space method. Features of the study of multidimensional systems. The concept of controllability and observability of multidimensional systems. Controllability and Observability Criteria. State space method as a modern method for describing multidimensional automatic control systems. Basic concepts of the state space. Input-state-output models. The concept of a state variable circuit. Direct, parallel and				

sequential programming method for charting state variables. Description of ACS by the state space method. The concept of a transition matrix. Methods for obtaining the transition matrix. Transfer matrix of transition. Transformations of forms of representation of models. Application of the state space method for digital modeling of ACS				
The main properties of the ACS: Stability and quality linear continuous systems of automatic management.	8	4	0	10
Topic 7. Basic concepts of the theory of stability. Analysis of the main properties of linear automatic control systems. Definition of the concept of "stability" of dynamical systems. Free and forced component of the transition process in the ACS. Characteristic control of ACS. Stability of ACS according to Lyapunov. Connection of the roots of the characteristic equation with stability Lyapunov's theorem. Topic 8. Criteria for sustainability. The concept of stability criterion. Algebraic stability criteria for automatic control systems: Hurwitz and Routh criteria. Frequency stability criteria. The principle of argument. Mikhailov's criterion. Corollary from Mikhailov's criterion. Nyquist criterion. Logarithmic stability criterion. Stability of ACS with a clean lag. Stability margins in modulus and phase. D-split. The concepts of structurally stable and structurally unstable systems. Topic 9. Quality of ACS transient processes. The concept of the quality of transients in linear ACS. The main indicators of the quality of transient processes: control accuracy, transient time, overshoot. Classification of methods for assessing the quality of processes. Direct methods for assessing the quality of ACS: methods for solving differential equations; operator method, digital and analog modeling method. Topic 10. Indirect methods for determining the quality of ACS. Specific features of indirect methods for assessing the quality of systems regulation. Root method. Vyshnegradsky's diagram. Frequency method of quality evaluation. Fourier transform as the basis of a particular method. Fourier transform as the basis of a particular method. The concept of generalized real frequency response. Application of the frequency method as a direct method for estimating control quality. Construction of transients by real frequency response (Solodovnikov's method). Indirect				

estimation of control quality indices by the type of real characteristic. Integral methods of ACS quality evaluation. Topic 11. Static and astatic ACS. Definition of static and astatic automatic control systems. Theorem on limiting (finite) value of a function. Definitions of static and astatic systems by control and perturbation channels. Degree of ACS astatism. Accuracy of ACS for various types of input actions. The concept of invariance and sensitivity of ACS.				
Methods of synthesis of linear constant ACS	16	8	4	20
Topic 12. Basic concepts of synthesis of linear ACS. The direct problem of automatic control theory. Formulation of the problem of synthesis of automatic control systems. Quality criteria and problems of selecting parameters and characteristics of ACS. Stages of design of automatic control systems. Different approaches to the synthesis of linear ACS. Correction of the dynamics of transition process by backlinks. Topic 13. Methods of synthesis of linear ACS. Correction of linear constant stationary systems. The concept of a correction device. The frequency method of synthesis (using the desired Bode graph). Construction of the desired Bode graph. Correction of systems by means of a series, parallel and counter-parallel (backlinks) correction device. The fundamentals of structural parametric optimization. Choice of desired transfer function of an object: binomial form, Butterworth filter, form providing minimum integral of weighted modular system error, form providing minimum transient. Typical control laws: P, I, D, PI, PD and PID. Advantages and disadvantages of typical regulators. Features of the synthesis of ACS of electromechanical systems. The method of subordinate regulation. Tuning of loops to a "technical" and "symmetrical optimum". Features of the synthesis of ACS by perturbation. Combined control. The basic purpose and calculation of the preceding filter. Principles of constructing invariant automatic control systems. The criterion of absolute invariance. Conditions for invariance with respect to controlling and disturbing actions. The concept of state regulators. Modal control.				
Total with regard to 5th semester	36	16	10	42
Total with regard to the course	**36**	**16**	**10**	**42**

Topics of exemplary practical work

№	Topic of practical (seminars) work
1	Drawing a circuit of ACS
2	Construction of transfer functions using the Laplace transform
3	Drawing a Bode graph of complex objects
4	Block diagrams of ACS
5	Quality assessment by the root method

Topics of laboratory work

№	Topic of laboratory work
1	Study the dynamic and frequency characteristics of the typical ACS links
2	The stability analysis of the continuous linear ACS
3	Study the quality of the linear automatic control systems
4	Study the typical control laws

5. Organizational and Pedagogical Conditions

5.1. Educational Technologies Used for Competences Formation

Holding lectures in the discipline is based on the active method of training in the process of which students are not passive but active participants of the lesson answering questions of the teacher. Teacher's questions are aimed at activating the process of learning material as well as at the development of logical thinking. The questions stimulating associative thinking and connecting new material with the previous one are identified by the teacher in advance.

Practical lessons are held by realization of the method based on active training: problem areas are determined, groups are formed. The following aims are pursued in the process of practical education: use of definite disciplines, knowledge and creative methods in solving problems and decision-making; students' skill-building of teamwork, interpersonal communication and development of leadership skills; consolidation of the basic theoretical knowledge.

Laboratory classes are based on an interactive learning method in which students communicate not only with the teacher but also with each other. At the same time, students ' activity in the learning process dominates. The teacher's place in interactive classes is reduced to orienting students ' activities to achievement of the goals of studies.

Interactive lectures, group discussions, role-playing games, training sessions, and analysis of situations and simulation models are used in academic studies.

5.2. Students' Manual for the Course Study

Learning the course, it is advisable for students to implement the following recommendations:

1. Learning of the discipline should be done systematically.
2. After learning one of the course units with the help of the text-book or lecture notes it is recommended to reproduce the basic terms, definitions, notions of the unit from memory.
3. Special attention should be paid to the reports on practical studies and individual complex tasks for self-work.
4. The topics list for individual study is given by the teacher at the lectures. The teacher also provides students with literary sources (first of all, new ones in the periodical scientific literature) for a more detailed understanding of the issues presented at the lectures.

6. List of Teaching Materials and Information Supply for Students' Self work in the Discipline

6.1. Paper-based courseware

№	Bibliographic entry (author, title, mode of publication, place, publishing house, year of publication, number of pages)	Number of copies in the library
	1. Basic literature	
1	Theory and applycation of digital control / Proceedings of the IFAC Symposium, New Delhi, India, 5-7 January 1982 / Oxford: Pergamon Press, 1982	1
2	Zhmud, V. A., Dimitrov, L. V., Nosek, J. Numerical Optimization of Regulators for Automatic Control System / 2019	
3	Emelyanov S. V. elected Proceedings (To the 85th Anniversary): Automatic Control Systems with Variable Structure. System Design of Automation Means. Binary Systems. New Feedback Types / Moscow : Krasand, 2014	1
4	Trunov G.M. Invariant form of equations of electromagnetism and Theoretical system of electromagnetic units / Perm: Publ. house Perm State Techn. Univ., 2006	6
	2. Additional literature	
	2.1. Educational and scientific literature	
1	Dorf R.C. Modern Control Systems / Reading, Massach : Addison-Wesley Publ. Co, 1990	1
2	Dorf R.C., Bishop R. H. Modern Control Systems / New Jersey : Pearson Educational Intern., 2005	1
3	Zamyatin S. V., Pushkarev M. I., Yakovleva E. M. Control theory / 2012 URL: elib.pstu.ru/Record/lan45137	
4	Flight dynamics principles: a linear systems approach to aircraft stability and control / New York: Elsevier, 2013 URL: elib.pstu.ru/Record/RUPNRPUelib4228	
5	Ioannou P. A., Kokotovic P. V. Adaptive Systems with Reduced Models / Berlin [et al.]: Springer-Verlag, 1984	1
6	2nd International Conference of Young Scientists "Solutions of Applied Problems in Control, Data Processing and Data Analysis", Koethen, Germany, 4 April 2011 / Perm: PSTU publ., 2011	2
	2.2. Periodical literature	
	Not used	
	2.3. Standardized and Technical literature	
	Not used	
	3. Students' manual in mastering discipline	
	Not used	
	4. Teaching and learning materials for students' self-work	
	Not used	

6.2. Electronic Courseware

Kind of literature	Name of training tool	Reference to information resource	Accessibility of EBN (Internet/local net; authorized/free access)
Additional literature	Zereyakob Minilik Control System Toolbox ™ User's Guide R2017b	URL: https://www.academia.edu/35999408/Control_System_Toolbox_Users_Guide_R2017b	free access
Additional literature	Karim Kabalan A linear control system simulation toolbox using spreadsheets	URL: https://www.academia.edu/28671321/A_linear_control_system_simulation_toolbox_using_spreadsheets	free access
Additional literature	Daniel E Rivera CR-IDENT: A Matlab toolbox for multivariable control-relevant system identification	URL: https://www.academia.edu/19329049/CR_IDENT_A_Matlab_toolbox_for_multivariable_control_relevant_system_identification	free access
Additional literature	Boris Polyak RACT: Randomized algorithms control toolbox for MATLAB	URL: https://www.academia.edu/2671469/RACT_Randomized_algorithms_control_toolbox_for_MATLAB	free access

6.3. License and Free Distributed Software used in the Course Educational Process

Type of Software	Software branding
Operating systems	MS Windows 8.1 (Azure Dev Tools for Teaching)
Office applications	Microsoft Office Professional 2007. licence 42661567
General purpose application software	MATLAB 7.9 + Simulink 7.4 Academic, PNRPU 2009
General purpose application software	Microsoft Office Visio Professional 2016 (Azure Dev Tools for Teaching)

6.4 Modern Professional Databases and Inquiry Systems Used in the Course Educational Process

Branding	Reference to information resource
Scientific Library of Perm National Polytechnic Research University	http://lib.pstu.ru/
Lan' Electronic library system	https://eJanbook.com/
IPR books Electronic library system	http://www.iprbookshop.ru/
Information resources of Consultant+ web	http://www.consultant.ru/

7. Logistics of the Course Educational Process

Type of classes	Name of the necessary basic equipment	Number of units
Laboratory work	PC with installed software: system block, monitor, keyboard, mouse	10
Lecture	Projector, screen, PC or laptop, whiteboard, marker, interactive whiteboard	1
Practicals	Projector, screen, PC or laptop, whiteboard, marker, interactive whiteboard	1

8. Fund of the Course Evaluating Tools

Described in a separate document