Federal State Autonomous Educational Institution of Higher Education
«RUDN University»

Engineering Academy

WORKING PROGRAM OF THE DISCIPLINE

Name of the discipline

Modern Problems of Control Theory

Recommended for the educational program

01.06.01 Mathematics and Mechanics

Focus of the program (profile)
Dynamics and strength of machines, devices and equipment» (technical sciences)

1. Aims and objectives of the discipline

The main objectives of the discipline "Modern Problems of Control Theory" are to gain knowledge about modern trends in the development of control theory, the formation of comprehensive practical skills necessary to solve problems related to the analysis and synthesis of control systems, the development of experience in applying mathematical apparatus to solve practical problems of optimal control, arising in practice.

The main objectives of the course are:

- To introduce modern concepts and concepts in management theory;
- to familiarise themselves with the specifics of the management tasks;
- To provide the necessary knowledge of the formulation and methods for solving optimisation problems, creating algorithms for optimum control.

2.Place of the discipline in the structure of the curriculum

The discipline " Modern Problems of Control Theory " refers to the variable part of block 1 of the curriculum.

Table 1 shows the previous and subsequent disciplines aimed at the formation of discipline competencies in accordance with the competence matrix of EP HE.

Table № 1

Prior and subsequent disciplines aimed at the formation of competencies

№	Code and name of competence	Preceding disciplines	Subsequent disciplines (groups of disciplines)
Universal competences			
1	ability to critically analyze and evaluate modern scientific achievements, generate new ideas when solving research and practical problems, including interdisciplinary areas (UC-1)	History and philosophy of science Dynamics and strength of machines, devices and equipment	
General professional competencies			
2	ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies (GPC-1)	Research methodology Priority areas for the development of mathematics and mechanics Dynamics and strength of machines, devices and equipment	
Professional competence			
3	willingness to apply promising research methods and solve professional problems, taking into account global trends in the development of technical	Research methodology Priority areas for the development of mathematics and mechanics	

	objects for various purposes (PC-1)	Dynamics and strength of machines, devices and equipment	
4	ability to identify the essence of scientific and technical problems arising in the course of professional activity, and to apply the physical and mathematical apparatus, theoretical, computational and experimental research methods, methods of mathematical and computer modeling, for solving the previously mentioned problems (PC-2)	Research methodology Dynamics and strength of machines, devices and equipment	
5	willingness to carry out research work and solve scientific and technical problems in the field of applied mechanics based on the achievements of engineering and technology, classical and technical theories and methods, physical-mechanical, mathematical and computational models that have a high degree of adequacy to real processes, machines and structures (PC-3)	Research methodology Priority areas for the development of mathematics and mechanics Dynamics and strength of machines, devices and equipment	
6	ability to create new generations of machines, devices, equipment, technologies and materials with qualitatively new functional properties, as well as to improve existing machines, devices, equipment and technologies with improved performance characteristics, less material and energy consumption (PC-4)	Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using informatics and computer technology in higher education Dynamics and strength of machines, devices and equipment	
7	ability to develop methods of mechanics and computational mathematics, computer technology and decision support systems in scientific research, design	Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using informatics	

	and engineering activities (PC-5)	and computer technology in higher education Dynamics and strength of machines, devices and equipment	
8	ability to study patterns and relationships, dynamic processes, stress states and strength of machines, devices and equipment (PC-6).	Priority areas for the development of mathematics and mechanics Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using informatics and computer technology in higher education Dynamics and strength of machines, devices and equipment	

To successfully master this discipline the student should have an understanding of modern concepts of control theory methods, understand the specifics of mathematical modelling of control tasks.

3. List of intended learning outcomes of the discipline

The discipline aims to develop the following competencies:

Universal competences	
UC-1	ability to critically analyze and evaluate modern scientific achievements, generate new ideas when solving research and practical problems, including in interdisciplinary fields
General professional competencies	
GPC-1	the ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies
Professional competences	
PC-1	willingness to apply promising research methods and solve professional problems, taking into account global trends in the development of technical objects for various purposes
PC-2	the ability to identify the essence of scientific and technical problems arising in the course of professional activity, and to apply for their solution the physical and mathematical apparatus, theoretical, computational and experimental research methods, methods of mathematical and computer modeling
PC-3	readiness to carry out research work and solve scientific and technical problems in the field of applied mechanics based on the achievements of engineering and technology, classical and technical theories and methods, physical and mechanical, mathematical and computer models that have a high degree of adequacy to real processes, machines and structures

PC-4	the ability to create new generations of machines, devices, equipment, technologies and materials with qualitatively new functional properties, as well as to improve existing machines, devices, equipment and technologies with increased operational characteristics, less material and energy consumption
PC-5	ability to develop methods of mechanics and computational mathematics, computer technology and decision support systems in scientific research, design and engineering activities
PC-6	the ability to study patterns and relationships, dynamic processes, stress states and strength of machines, devices and equipment

As a result of the course, the student should:

Know: basic concepts and definitions of optimal control theory, basic algorithms for building software.

To be able to: be fluent in all basic concepts, theoretical results and algorithms of control theory, to formulate and solve specific applied problems of optimisation and optimum control.

Mastery*: the* mathematical apparatus of the theory of optimum control.

4 The scope of the discipline and types of study:

The course consists of **3 credit units (108 hours).**

Type of study	**Total hours**	**Semester**
		3
Classroom activities (total)	**20**	20
Including:		
Lectures	**-**	-
Practical exercises (PP)	**20**	20
Seminars (C)	**-**	-
Laboratory work (LW)	**-**	-
Independent work (total)	**88**	88
Monitoring	**-**	-
Total time commitment per hour	**108**	108
credit unit.	**3**	3

5. Content of the discipline

5.1 Content of the sections of the discipline

Section 1. Basic concepts of management theory

Basic concepts and principles of governance. Laws of control. Classification and mathematical description of control systems. Linearisation. Standard form of writing a link equation.

Section 2: Optimisation tasks in management processes

The calculus of variations and the Pontryagin maximum principle. Euler's equation. Solution of tasks for finding extrema. Verification of extrema. Phase limitation in optimal control problems. Solution of tasks for synthesis of optimal trajectories under phase constraints. Tasks for compiling Bellman equations in differential form. Solving problems of resource allocation by dynamic programming. Dynamic programming.

Section 3: Typical links and structure of automatic control systems

Laplace transform. Transfer functions. Typical ACS links. Transfer matrix. Solution of linear differential equations with Laplace transforms. Characteristics of typical links. The rules for transforming structural diagrams. Multidimensional automatic control systems (ACS). Determining the characteristics of ACS parts. Transfer functions of series-connected links. Transfer functions of parallel connected links. Transfer function of a closed-loop system. Partial transfer functions.

Section 4: Concepts of sustainability, manageability, observability, identifiability

Stability of automatic control systems. Controllability and achievability. The study of the stability of ACS. Mikhailov's criterion. Nyquist criterion. Controllability and attainability equivalence. Observability and identifiability.

Section 5: Methods for finding an extremum

A non-linear programming problem. Level hypersurfaces. Solving nonlinear programming problems using level hypersurfaces. Necessary condition of extremum of a differentiable function. Sufficient condition of extremum. Criteria of positive and negative definiteness of a quadratic form. The directional derivative. The gradient of a function and its properties. The theorem on gradient direction. Gradients as normals to level lines. The method of descent. The method of step splitting. The problem of finding an extremum of a unimodal function. The brute force method. The method of splitting in half. The golden ratio method. Chord (Secant) method. Newton's method.

Section 6. Lagrange function, Kuhn-Tacker conditions and convex programming problems

The rule of indefinite multipliers in the problem of finding a conditional extremum of a function of two variables. Necessary condition of an extremum in a general mat-programming problem with constraints of equality type. Method of Lagrange multipliers. Cone, examples of cones. The Farkasch theorem. The concept of possible direction, examples. Regularity conditions. Kuhn-Tucker theorem. Geometrical interpretation of Kuhn-Tucker conditions. Kuhn-Tucker conditions for equality type constraints. The maximin and minimax of a function of two variables and the lemma on the relation between them. The concept of a saddle point. Examples of the existence and absence of saddle points. A necessary and sufficient condition for the existence of a saddle point. The notion of a dual problem, the duality relation. The saddle point theorem for a Lagrange function. Duality theorem for linear programming problems. Smooth extremal problems in normed spaces. Lagrange multiplier rule. Smooth problems with constraints of equality and inequality type, necessary and sufficient conditions of extremum.

5.2 Sections of the disciplines and types of classes (full-time)

No. n/a	Name of discipline section	Л	С	PP	SRS	Total hour.
1.	Section 1 Basic concepts in management theory	3		3	12	18
2.	Section 2: Optimisation tasks in management processes	3		3	12	18
3.	Section 3: Typical links and structure of automatic control systems	3		3	12	18

4.	Section 4: Concepts of sustainability, manageability, observability, identifiability	3		3	12	18
5.	Section 5: Methods for finding an extremum	4		4	10	18
6.	Section 6. Lagrange function, Kuhn-Tacker conditions and convex programming problems	4		4	10	18
	Total	20		20	68	108

6. Laboratory workshop - not foreseen

7 Practical exercises (workshops)

No. n/a	Discipline section no.	Topics of practical exercises (seminars)	Labour-capacity (hour).
1.	1	Mathematical description of control systems. Linearisation. Standard form of a link equation	1
2.	1	Euler's equation. Solving problems to find extrema. Verification of extrema. Pontryagin's maximum principle	2
3.	1	Solving optimal trajectory synthesis problems using Pontryagin's principle	1
4.	2	Solving the problem of optimal trajectory synthesis under phase constraints	1
5.	2	Tasks for composing Bellman equations in differential form. Solving dynamic programming problems for resource allocation	2
7.	3	Solution of linear differential equations using Laplace transforms. Transfer functions and transfer matrices	1
8.	3	Determination of the characteristics of ACS links. Transfer functions of sequentially connected links. Transfer functions of parallel connected links. Transfer function of a closed-loop system. Partial transfer functions.	1
9.	4	Stability of automatic control systems. Controllability and achievability.	1
10.	4	A study of the stability of ACS. Mikhailov criterion. Nyquist's criteria.	1
11.	4	The equivalence of controllability and attainability. Observability and identifiability**.**	1
12.	5	Examples of linear and non-linear programming problems. Level hypersurfaces. Solution of nonlinear programming problems using level hypersurfaces. Necessary condition of extremum of a differentiable function. Sufficient condition of extremum. Criteria for positive and negative definiteness of a quadratic form.	1
13.	5	Finding directional derivatives. Finding the directions of the largest increasing (decreasing) functions. Gradients and normals to level lines. The method of shortest descent. Split step method. Frank-Wolfe method. Coordinate descent.	1
14.	5	The problem of finding an extremum of a unimodal function. The brute force method. The method of splitting	1

		in half. The Golden Ratio method. The method of chords (secants). Newton's method. Modified Newton's method.	
15.	6	Fibonacci method. Solving mathematical programming problems with equality type constraints.	1
16.	6	Examples of cones. Possible directions, examples. Regularity conditions. Kuhn-Tucker theorem. The geometrical interpretation of the Kuhn-Tucker conditions. Kuhn-Tucker conditions for equality type constraints. Kuhn-Tucker conditions for linear programming problems.	1
17.	6	Examples of the presence and absence of saddle points in functions with two groups of variables. Binary linear programming problems.	1
18.	6	Euler's equation. The integrals of the Euler equation. The Boltz problem. The isoparametric problem.	1
		Total:	20

8 Indicative topics for research papers

1. Analysis of the sequence and time costs of operations on the conveyor belts of the "Name of the plant(s)".
2. Solving discrete optimisation problems by dynamic programming.
3. An application of the traveling salesman problem to the synthesis of optimal service schedules for spatially dispersed objects.
4. Tasks of servicing stationary objects by a processor moving in a one-dimensional area.
5. Solving the problem of the traveling salesman by dynamic programming.

9 List of information technologies used in the education process

1. Computer technology;

2. Multimedia presentations;

3. testing programmes;

4. information resources.

10 Description of the facilities

E-learning materials used in the educational process, multimedia presentations, a bank of tests, etc. are available on the TUIS and Web-local portals.

11 List of information resources used in the discipline (module)

- textbooks;

- training manuals;

- teaching aids;

- scientific literature;

- Internet materials.

12 List of basic and additional literature

(a) Basic literature

1. Burkov V. N., Korgin N. A., Novikov D. A. Vvedeniye v teoriyu upravleniya organizatsionnymi sistemami: Uchebnik / Pod red. D. A. Novikova. – M.: Knizhnyy dom "LIBROKOM", 2009.
2. Vasin A. A. Issledovaniye operatsiy: ucheb. posobiye dlya studentov vuzov. – M.: Akademiya, 2008. – 464 s.
3. Vdovin V. M. Teoriya sistem i sistemnyy analiz: Rek. GUU v kach. uchebnika dlya vuzov/V. M.Vdovin, L. Ye.Surkova, V. A.Valentinov.-2-ye izd. – M.: ITK "Dashkov i K", 2012. – 638 s.
4. Moiseyev N. N. Matematicheskiye zadachi sistemnogo analiza. – M.: Librokom, 2012. – 490 s.
5. Sobol' B. CH., Meskhi G. I., Kanygin B. V. Metody optimizatsii: Praktikum. – Rostov na Donu: Feniks,2009.

b) further literature

6. Alekseyev V. M., Galeyev E. M., Tikhomirov V. M. Sbornik zadach po optimizatsii. – M.: FIZMATLIT, 2005. – 256 s.
7. Yevmenov V. P. Intellektual'nyye sistemy upravleniya. -M.: LIBROKOM, 2009. – 304 c.
8. Yesipov B. A. Metody issledovaniya operatsiy – SPb: Lan', 2010.
9. Korneyenko V. P. Metody optimizatsii. Dopushcheno UMS po prikladnoy matematike i informatike UMO v kachestve uchebnika dlya studentov VUZov po spetsial'nosti «Prikladnaya matematika i informatika». - M.: VYSSHAYA SHKOLA, 2007.- 664 s.
10. Miroshnik I. V. Teoriya avtomaticheskogo upravleniya. Lineynyye sistemy. Piter, 2005.
11. Panteleyev A. V., Bortakovskiy A. S. Teoriya upravleniya v primerakh i zadachakh.-M., Vysshaya shkola, 2003.
12. Sukharev A. G., Timokhov A. V., Fedorov V. V. Kurs metodov optimizatsii.- M.: Moskva, FIZMATLIT, 2005.

13. Methodological guidelines for students to master the discipline (module)

Course implementation includes interactive lectures, practical classes (seminars) using multimedia equipment, preparation of independent creative works and their subsequent presentation, testing, group discussions on the subject of the course, modern technologies of knowledge control.

In studying the course, the student must attend lectures, take the number of seminars provided in the syllabus, study some topics of the course independently and confirm his/her knowledge in the control activities.

A student's work during a lecture consists of understanding the basics of the discipline, briefly outlining the material, and clarifying the issues that cause difficulties. The lecture notes are the basic study material along with the textbooks recommended in the main list of literature.

The main part of the lecture material is taught using multimedia, which facilitates perception and memorization of the material. Presentations are available for download from the PFUR website and can be freely used by students for learning purposes.

A student is obliged to master all the topics provided for in the syllabus of the discipline. Individual topics and issues of study shall be taken up for independent study. The student studies the recommended literature and takes brief notes on the material, and clarifies the most complex

issues that require clarification during tutorials. The same applies to the sections of the course that have been omitted due to various circumstances.

For in-depth study, the student should consult the literature in the supplementary list and specialised websites on the Internet. It is also recommended that students communicate in professional community forums.

Students independently study academic, scientific and periodical literature. They have the opportunity to discuss what they have read with the teachers of the discipline during scheduled consultations, with other students in seminars and during lectures by asking clarifying questions to the lecturer.

Master students' independent work is monitored by the Lead Instructor. Depending on the teaching methodology, the following forms of current control may be used: brief oral or written questioning before the start of classes, written homework, essays, etc.

Requirements for writing essays, term papers

The essays and term papers are written in accordance with the requirements set out in the "Provisions on graduate work of Peoples' Friendship University of Russia", approved by the RUDN Rector's Order № 856 from 08.09.2015.

The coursework is up to 20 ... 30 pages long.

Glossary of key terms and concepts

MATHEMATICAL MODEL ADAPTABILITY is the correspondence of a mathematical model (MM) to an object with respect to the reflection of given properties of the object. Usually, MM is considered adequate if calculation errors caused by application of the tested model do not exceed the stipulated limit values.

A design algorithm is a set of instructions required to carry out a design (GOST-22487-77).

An ALGORITHMIC MODEL is a mathematical model represented in the form of an algorithm that processes a set of inputs into a set of outputs.

ANALYSIS is the study of objects and phenomena of the environment based on the study of their internal structure, patterns of behaviour or the external manifestation of their properties. The analysis in CAD is a design procedure or a group of design procedures aimed at obtaining information about the properties of a given designed object.

An ANALYTICAL MODEL is a mathematical model that is a set of analytical expressions and dependencies that allow the evaluation of certain properties of the object being modelled.

ARIPHMETIC~LOGICAL DEVICE - (ALU) is a device that performs arithmetic and logical operations on machine words (operations) during the information conversion process.

ARM - automated workplace.

DATABASE is a pool of information that allows for the optimisation of the water, output and processing of information.

KNOWLEDGE BASE is a formalised body of information about a subject area, containing data about the properties of objects, patterns of processes and phenomena and the rules for using this data in given situations to make new decisions.

METHOD BASIS is a vector of variables describing the state of an object.

DATA BANK - a set of databases (DBs) and DBMSs, as well as technical, linguistic and organisational tools for the centralised accumulation and collective multidimensional use of data.

BARRIER FUNCTION is a penalty function to keep the search trajectory within a valid area.

The database is a pool of information that allows you to optimise information input, output and processing

The unrestricted EXTREME of a target function is the largest or smallest value of F(X) found in an unrestricted space of controllable parameters.

A DATA BLOCK is an assembly of data sent to an external device or read into RAM as a single entity.

BLOCK~MULTIPLEX CHANNEL - A computer I/O channel designed for parallel operation of several peripheral devices.

The approach is to break down the understanding of the design object, including models, design problem statements, design documents, etc., into a number of hierarchical levels (levels of complexity or abstraction).

VERIFICATION is an analysis whose purpose is to establish whether the synthesised structure is consistent with the original description.

PROBABILITY is a measure of whether an event is likely to occur. GOST R 50779.10 provides a mathematical definition of probability: 'a real number in the range 0 to 1 relating to a random event'. The number can reflect the relative frequency in a series of observations or the degree of certainty that some event will occur.

A GRAPH'S ARCHIVE - two vertices in a graph are called adjacent if they are connected by an edge (arc), and two different arcs (edges) are adjacent if they have one vertex in common.

VETWEEN is the control structure for decision-making during a computational process.

Inclusion of each chord in turn in the branches of the tree.

EXTERNAL DEVELOPMENT - a design, the purpose of which is to develop a design specification that contains the basic requirements of a technical system and its interaction with the environment, ensuring that the objectives of the system are met.

EXTERNAL PARAMETERS - (variables) are values that characterise the properties of the environment external to the object under study.

INTERNAL DESIGN is a design that aims to develop all the necessary design documentation to produce a design that meets the requirements of external design.

INTRODUCTION PARAMETERS - (element parameters) are quantities that characterise the properties of elements.

The term "bottom-up design" is used when the execution of procedures in lower hierarchical levels precedes the execution of procedures belonging to higher hierarchical levels.

EXECUTIVE LANGUAGE is a language for representing the results of design procedures or design routines performed on a computer.

OUTPUT PARAMETERS are quantities that characterise the properties of systems.

OUTPUT PARAMETERS~FUNCTIONS are output parameters that are functionals of the dependencies of phase variables on time or frequency.

A CALCULATING SYSTEM is an interconnected set of computer hardware and software designed to process information.

A CALCULATING COMPLEX is an interconnected and geographically concentrated set of one or more computers and various peripheral equipment.

A HYPERGraph is a graph in which edges represent n-local relations between vertices (n>=2), i.e., each edge is a subset of incident vertices.

HIP AUTOMATIZED PRODUCTION is the production of products based on comprehensive automation of the technological process itself, aimed at changing the properties of the processed objects, such operations of the production process as product quality control, diagnosis of technological equipment, storage and transport of objects or parts, as well as procedures and operations design and technological preparation of production of objects to be manufactured.

GLOBAL EXTREMUM OF FUNCTION F(X) is the lowest (or highest) value of F(X*), for which the relation F(X*) =<F(X) (or F(X*)>=F(X)) must hold for all points X in the definition of function F(X).

A GRAF is a set of line segments when a bipole is replaced by a line segment, since each bipole will be assigned a direction, the graph is directional.

GRAPHOPOSTER - reproduce a graphic image on paper by means of electromechanical or magneto-mechanical movements of the writing unit.

DECOMPOSITION - the representation of an object by degree of detail into hierarchical levels.

A GRAF TREE is a linked subgraph with no cycles.

A TREE OF RELATED GRAPH is a connected subgraph that includes all the nodes of the graph and does not contain any closed contours.

DISCRETIZATION OF TASK - replacing a continuous problem with a discrete one.

DYNAMIC PROGRAMMING IS THE phased planning of a multi-step process in which only one step is optimised at each step. The control in each step must be chosen with all its consequences in the future in mind.

THE VARIANCE OF A RANDOM VARIABLE is a measure of the spread of that random variable, that is, its deviation from the mathematical expectation.

DECISION MAKING TASK (DMT) - seeks to determine the best (optimal) course of action to achieve the objectives.

INDEPENDENT SOURCE - a source of a flux-type or potential-type variable that is dependent either on time or on phase variables.

A design brief is a primary description of the object of design, presented in a given form. (GOST-22487-77).

The ROTARY CHALLENGE is the task of determining the nominal values of component parameters at given tolerances for these parameters, reducing to such an arrangement of the tolerance area in the component parameter space that its intersection with the serviceability area has the maximum volume.

The capacity reserve is a value that characterises the extent to which the performance condition is fulfilled.

IDENTIFICATION - the establishment of a correspondence between an object represented by some set of experimental data about its properties and one of the descriptions from a given set of descriptions (models) of the object.

A hierarchical DATA MODEL is a data model in which only one source record can exist for a subordinate record.

HIERARCHIC LEVEL - A level of abstraction in the description of an object in a block-hierarchical approach to design.

The simulation model is a mathematical model that represents the behaviour of a simulated object under given time-varying external influences.

INVARIANT SUB-SYSTEMs are subsystems that perform unified procedures and operations that make sense for many types of design objects.

INTERFACE is a device that coordinates the operation of individual units by logic signal levels and connector designs.

INFORMATION SOFTWARE is a set of information in a given form necessary to perform computer-aided design, including descriptions of standard design procedures, standard design solutions, standard elements, components, materials, etc. The main part of information support is databases.

COMPONENT - An indivisible part of a chip that cannot be specified and supplied as a separate product, e.g., transistor, resistor, diode, interconnection areas.

COMPONENT LEVEL - A level that looks at the processes that take place in the circuit components.

CONSTRUCTOR DEVELOPMENT - selection of form, layout and positioning of the structures, tracing of interconnections, production of design documentation.

CONTOUR - a cycle in a graph that does not contain repeating vertices.

A coefficient that describes the sensitivity of an output parameter to changes in an input parameter.

LINGUISTIC SUPPORT is a set of languages, terms, definitions required to perform computer-aided design.

A LINEAR ALGORITHM is an algorithm in which actions are carried out one after the other.

LOGICAL MODELING is the derivation of a mathematical model of an object in the form of a system of logical equations and its use in design procedures.

LOCAL EXTREME OF FUNCTION F(X) is the lowest or highest value of F(X*). A function F(X) has a minimum at point X* if there exists e>0, where for any point X satisfying the condition ABC(X-X*) <e, the condition F(X)=<F(X*) holds, and has a maximum if F(X)>=F(X*).

MAXIMUM CRITERIUM is an optimality criterion based on selecting as the maximised target function F(X) the output parameter that, at a given point X of the search trajectory, is the worst match for the requirements of the specification.

A path in a graph is a sequence of adjacent edges. Adjacent edges are edges that are incident to the same vertex.

A mathematical model is a set of mathematical objects (numbers, variables, sets, matrices, etc.) and the relationships between them that adequately represent some of the properties of a technical object of interest in a study.

MATHEMATICAL DEVELOPMENT is a set of mathematical methods, algorithms and models necessary to perform computer-aided design.

THE MATHEMATICAL EXPECTATION is the mean value of a random variable (this is the probability distribution of a random variable, considered in probability theory)

Incident matrix is a matrix that stores information about the relationships between elements in an object. When modelling, an incident matrix can store information about the structure of a graph. The columns of this matrix correspond to the branches of the graph, the rows to the nodes.

CONTOUR AND SECTION MATRIX - (M-MATRIC) is a matrix that stores information about the structure of a graph, provided that the graph has a fundamental tree. The columns of the matrix correspond to the branches of the tree, the rows to the chords.

CONNECTIVE MATRIX is a matrix that stores information about the structure of a graph in the following form: matrix rows and columns correspond to nodes of the graph; if nodes are connected by an edge, at the intersection of corresponding rows and columns we put <<1>>, if not - <<0>>.

NEEDING METHOD is a gradient-based search minimisation method in which the search is carried out in an anti-gradient direction with an optimum step.

PRIRATION METHOD is a method of sensitivity analysis based on numerical differentiation of the dependence of output parameters on internal (or external) parameters.

SIMPLE ITERATION METHOD is a method for solving a system of algebraic equations of the form F(X)=0, based on the iteration formula X^(R+1)=X^R+hF(X^R), where h is an iteration process parameter; R is an iteration number.

A random search method is an optimisation search method in which the choice of search direction (or enumeration of points) in the controlled parameter space is made according to some random vector distribution law.

METHODOLOGICAL SUPPORT - documents that describe the composition, selection and operation of design automation tools.

A multivariate analysis is the determination of a vector of output parameters Y for given changes in the values of feature vectors X and external parameters Q. Typical multivariate analysis procedures include:

Multiple-variant ANALYSIS is a multiple solution to the problem of determining RPS output parameters when input parameters change, including multiple single-variant analysis and inter-variant modifications of its input parameters (GOST-23070-78).

The term 'modelling' refers to the study of a physical object by creating a mathematical model of the object and manipulating it in order to obtain useful information about the physical object.

Modelling is the study of an object by creating a mathematical model of it and manipulating it in order to obtain useful information.

INAUTOMATIZED DEVELOPMENT - a design in which all transformations of object descriptions and (or) its functioning algorithm or process algorithm, as well as presentation of descriptions in different languages are carried out by a human. (GOST-22487-77)

NON-LINEAR PROGRAMMING (NLP) is a mathematical programming problem in which either the target function or the constraint, or both together, are non-linear functions.

OBJECT SUBSYSTEMs are subsystems in which procedures and operations directly related to a specific type of design object are carried out.

OUTPUT PARAMETER LIMITATIONS - (output parameter specifications) - limit values of the output parameter variation ranges allowed by the specification.

ODEs are homogeneous differential equations.

Defines the gradient of the function that is used in the parametric optimisation of the circuit.

AN ORDINAL FLOW OF EVENTS - the probability of Δt falling within an elementary interval of length is small compared to the probability of a single event falling within that interval.

OPTIMAL SOLUTION is a vector of controllable parameters X*=(x1*...xn*) that satisfies all constraints, delivering an extremum value of the target function at the optimal point, i.e. F(X*).

The optimization is an optimization that solves the problem of determining the nominal value of an internal parameter while optimizing the tolerances, additional tolerances for internal parameters are determined.

OPTIMIZATION - (parametric optimisation) is the achievement of an extremum of some target function.

ORGANISATION SUPPORT - a set of documents establishing the composition of the design organisation and its subdivisions, their functions, links between them and the design automation complex, the form, composition and list of design documentation.

A PARAMETER is a value that characterises a property or mode of operation of an object.

PARAMETRICAL OPTIMISATION is a design procedure aimed at selecting the optimality criterion and determining the values of the parameters of the elements of the designed object that are best from the point of view of the chosen criterion, provided all the constraints are met and the structure of the object is given.

PARAMETRICAL SYNTHESIS - determines the numerical values of element parameters given the structure of the object and the range of possible changes in external variables.

THE DISTRIBUTION DENSITY (OR PROBABILITY DENSITY) - of a continuous random variable X at point x is the derivative of its distribution function at that point and is denoted by f(x).

A FLOW OF EVENTS is a sequence of events happening one after the other at some point in time.

PREFERENCE IS AN integral assessment of the quality of decisions, based on objective analysis (knowledge, experience, experiments and calculations) and a subjective understanding of the value, effectiveness of decisions.

SOFTWARE is a collection of programs presented in a given form, together with the required program documentation.

DESIGN is the process of creating descriptions of a new or modernised object (system, process) sufficient to be manufactured or implemented under given conditions. This description is obtained as a result of an initial transformation presented in the form of a ToR.

PROJECTING SUB-SYSTEMS are the subsystems that carry out the project procedures and operations.

The project procedure is an action or set of actions that form part of the project procedure, the algorithm for which remains the same for a number of project procedures.

A PROJECT PROCEDURE is a formalised set of activities which culminate in a PROJECT DECISION.

A PROJECT DECISION is an intermediate or final description of a design object, necessary and sufficient for consideration and determination of further direction or completion of the design.

PROJECT OPERATIONS - an action or set of actions of algorithms whose execution remains unchanged for a number of project procedures.

The project is a formalised set of activities culminating in the adoption of a project decision.

A work programme is a programme directly used in solving a specific project task.

WORKING PROJECT - complete design documentation sufficient to manufacture .... technical systems under specified conditions (under specific production conditions).

Matrix DILUTION is the presence of a large number of zero elements in a matrix.

RESULT OF DESIGN is a design solution (a set of design solutions) that satisfies the specified requirements, necessary for the creation of the object of design (GOST-22487-77).

A GRAPH branch crossing is the set of edges intersected by a closed crossing line, provided that any edge is crossed no more than once and that among the branches of the tree there is only one intersection.

A SYSTEM is a set of elements in relationship and relationship to each other, which forms a certain integrity, a unity.

A MASS SERVICE SYSTEM (MSS) is a system consisting of a flow of requests and the devices serving those requests.

AUTOMATIC DESIGN SYSTEM is a set of design automation tools interconnected with the necessary subdivision of the design organisation or a team of specialists (system user) that performs automatic design (GOST-22487-77).

SYSTEM DESIGN - analysis of the tactical and technical requirements of the system to be designed, definition of the basic principles of operation, development of structural diagrams.

SYSTEM LEVEL - A level where systems are systems, e.g. computer, radar, control system for a moving object, and elements are hardware units (devices), e.g. processor, modem, transmitter, etc.

STATISTICAL ANALYSIS is the estimation of the law and/or numerical characteristics of the distribution of the output parameter vector Y given statistical information about the distribution of the random parameter vector X.

A STEADY-STATE FLOW OF EVENTS - if the probability of a given number of events falling within a time interval of length $\left[t_1, t_1 + \Delta t\right] \Delta t$ only on Δt, and is independent of, the initial moment t1.

STATIONARY POISSON FLOW OR SIMPLE FLOW is a stationary ordinal flow without an aftereffect.

LIFE CYCLE STRUCTURE - a process structure developed by the production and operation of technical systems covering the period of time from the inception of an idea to its utilisation.

OBJECT STRUCTURE is the composition of the elements of an object and their connections to each other.

STRUCTURAL SYNTHESIS - defines the structure of an object.

The design of an object is determined by the structure of the object to be designed.

DBMS - a database management system. For example: ACCEC, DBASE, FOXPRO, etc.

A SUBGRAPH is a part of a graph formed from the original graph by removing some of its edges.

FIGURE FUNCTION of an RPS is a ratio of two quantities, which can be currents and voltages at the inputs and/or outputs of an RPS, represented as a function of a complex variable (GOST-23070-78).

Schematic level - a level in which functional units are described as systems consisting of electrical and radio components (circuit components - transistors, resistors, capacitors, etc.).

Schematic design - development of functional and schematic diagrams.

TC is a technical system.

The term "engineering support" refers to a set of interrelated and interacting technical means for entering and storing, processing, transmitting programmes and data, organising human communication with the computer, and producing project documentation.

The TECHNOLOGICAL ASPECT is an aspect that considers the hierarchical levels of description of technological processes in the form of principle diagrams, routes, sets of operations and transitions.

TECHNOLOGICAL COMPLEX - a set of technical means for the presentation of project documentation and the preparation of programmes (control programmes) on special media.

TECHNOLOGICAL DESIGN - development of routing and operating procedures, selection of tooling, definition of process bases.

TOR - Terms of Reference.

A TYPE DESIGN DECISION is an existing design solution used in the design (GOST-22487-77).

The search trajectory is a conditional line connecting the points in the controlled parameter space that are taken as the results of the steps in the search engine optimisation process.

LEVELS OF ABSTRACT - levels that differ in the degree of detail of the views of the design object.

The OPERATION CONDITION is the condition that ensures the ratio of Yi to Ti required by the specification. Yi - element of the vector of output parameters. Ti is the element required by the specification.

The extremum of the target function F(X*) found in the presence of constraints.

The stability of a numerical method is the property of a multi-step numerical method to keep the total error of the numerical solution of the problem limited at each step of the computational process.

PHASE PREMISES are quantities that characterise the physical or information state of an object.

A FUNDAMENTAL TREE is a connected subgraph that has no cycles (the fundamental tree spans all vertices of the graph and does not form any cycles).

FUNCTIONAL MODEL is a mathematical model reflecting the physical or information state of the object under study and/or the processes of changing states.

HORD is an edge of a graph not included in the tree.

A TARGET FUNCTION is a function whose extreme value is sought on an admissible set in mathematical programming problems.

SOLUTION EFFICIENCY is the degree to which the objectives are achieved, divided by the cost of achieving them. The more effective the solution, the greater the degree of achievement of the objectives and the lower the cost.

A GRAPH CHAIN is a route in a graph in which all the edges are different.

A GRAPH CYCLE is a closed circuit of a graph.

A sensitivity is some numerical value that provides additional information about the behaviour of a system:

The step of ODE INTEGRATION is the interval h between two adjacent sampling points on the independent variable axis in the numerical integration of the ODE.

EQUIVALENT FIGURE is a representation of the structure of a technical object by means of symbolic representations of its constituent elements.

A design stage is a conventionally defined part of the design process consisting of one or more design procedures. It usually includes procedures related to obtaining descriptions within one aspect and one or more adjacent levels of abstraction.

The simulation language is the design language in which the input information for running the simulation of the object under investigation is specified.

14.Assessment tools (FES)

14.1 Description of the point rating system

The assessment is based on the student's work in seminars, written tests, essays, presentations and oral examination of all course topics. Attendance at seminars is also taken into account.

Students are assessed in the Modern Problems of Management Theory course using a credit system:

The maximum number of points is 100.

The maximum number of points for:

1. Class attendance - 20 points
2. Surveys. Problem solving - 20 points
3. Completion of homework - 10 points
4. examination (CR) - 20 points
5. exam - 30 points

A system for assessing students' knowledge:

№ n/a	Contents	Number of points
1.	Attending lectures and seminars	0-20
2.	Problem solving in seminars, participation in surveys, discussions	0-20
3.	Homework (homework) : - Problem-solving from various industry sectors	 0-10
4.	Attestation work: - intermediate (CD) - final	 0-20 0-30
	TOTAL:	0-100

Assessment by topic, broken down by form of control

Section	**Theme**	Forms for monitoring the level of mastery of				
		Attending lectures and seminars	Surveys, problem solving at seminars	Fulfilment of the TOR	Scores of the topic (total)	Section score (total)
Section 1: Basic concepts in management theory	Mathematical description of control systems.	2	2	1	5	5

Section 2: Optimisation tasks in management processes	Solving problems to find extrema	2	2	1	5	20
	Solving the problem of optimal trajectory synthesis under phase constraints	2	2	1	5	
	Bellman equation problems in differential form.	2	2	1	5	
	Dynamic programming solution to resource allocation problems	2	2	1	5	
Section 3: Typical links and structure of automatic control systems	Solution of linear differential equations using Laplace transforms.	2	2	1	5	10
	Determination of the characteristics of ACS links. Transfer functions of sequentially connected links. Transfer functions of parallel connected links. Transfer function of a closed-loop system.	2	2	1	5	
Section 4: Concepts of sustainability, manageability, observability, identifiability	Stability of automatic control systems.	2	2	1	5	5
Section 5: Methods for finding an extremum	The problem of finding an extremum of a unimodal function. The brute force method. The method of splitting in half. The Golden Ratio method. The method of chords (secants). Newton's method. Modified Newton's method.	2	2	1	5	5
Section 6. Lagrange function, Kuhn-Tacker conditions and convex programming problems	Binary linear programming problems.	2	2	1	5	5
TOTAL	**100**	**20**	**20**	**10**	50	50

Compliance of grading systems (previously used grades of final academic achievement, ECTS grades and grading-rating system (GRS) of assessments of current progress) (In accordance with the Rector's Order No. 996 of 27.12.2006)

Points BRS	Traditional assessments in the Russian Federation	**Points for transfer** assessments	Assessments	Assessments ECTS

86 - 100	5	95 – 100	5+	A
		86 – 94	5	B
69 - 85	4	69 – 85	4	C
51 - 68	3	61 - 68	3+	D
		51 - 60	3	E
0 - 50	2	31 - 50	2+	FX
		0 - 30	2	F

Explanation of the grading table:
Description of ECTS grades

A	***"Excellent"*** - the theoretical content of the course has been fully mastered without any gaps, the necessary practical skills to work with the mastered material have been formed, all the learning tasks in the study programme have been completed, the quality of their performance is assessed with a number of points close to the maximum**.**
B	***"Very good"*** - the theoretical content of the course has been fully mastered without any gaps, the necessary practical skills to work with the mastered material have been mostly formed, all the learning tasks in the curriculum have been completed, the quality of most of them has been assessed as close to the maximum number of points.
C	***"Good"*** - the theoretical content of the course has been fully mastered without any gaps, some practical skills in working with the mastered material have been insufficiently formed, all the learning tasks in the curriculum have been completed, none of them has been assessed with a minimum score, some types of tasks have been completed with mistakes**.**
D	***"Satisfactory"*** - the theoretical content of the course has been partly mastered, but the gaps are not significant, the necessary practical skills to work with the mastered material have been mostly formed, most of the curriculum tasks have been completed, some of the completed tasks may contain mistakes.
E	***"Intermediate"*** - the theoretical content of the course has been partly mastered, some practical work skills have not been developed, many of the curricular tasks have not been completed, or the quality of some of them has been assessed as close to the minimum number of points.

FX	***"Conditionally unsatisfactory"*** - the theoretical content of the course has been partially mastered, the necessary practical work skills have not been formed, most of the learning tasks in the curriculum have not been completed or the quality of their completion is assessed as close to the minimum; with additional independent work on the course material, the quality of completion of the learning tasks can be improved.
F	***"Absolutely unsatisfactory"*** - the theoretical content of the course has not been mastered, the necessary practical work skills have not been formed, all completed course assignments contain gross errors, additional independent work on the course material will not lead to any significant improvement in the quality of the course assignments.

The system is based on the calculation of points earned by the student during the semester. Most of the points a student earns during the study process by completing all types of coursework on time, while a smaller portion is earned in examinations.

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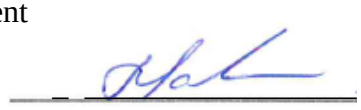
Microsystem Technology  M.O. Makeev

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