Federal State Autonomous Educational Institution of Higher Education «Peoples' Friendship University of Russia»

Engineering Academy

_____
(faculty/institute/academy)

Recommended by the MSSN

WORKING PROGRAM OF THE DISCIPLINE

Name of the discipline is Applied Methods of the Numerical Solutions of Optimal Control Problems

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It is recommended for the direction of training/specialty

09.06.01 «Computer science and engineering»

Orientation of the program (profile)

System analysis, management and information processing

1. Goals and objectives of the discipline: The main goals of mastering the discipline "Applied Methods of the Numerical Solutions of Optimal Control Problems" are to gain knowledge about modern trends in the development of control theory, the formation of complex practical skills necessary to solve problems related to the analysis and synthesis of control systems, the development of experience in using mathematical apparatus to solve practical problems of optimal control that arise in practice.

The main objectives of the course are:

- introduce modern concepts and concepts of management theory;
- to familiarize with the specifics of management tasks;
- provide the necessary knowledge about the statements and methods of solving optimization problems, creating optimal control algorithms.

2. The place of the discipline in the structure of the OP VO:

The discipline Modern problems of management theory belongs to the most *variable* part of the curriculum.

Table № 1 shows the previous and subsequent disciplines aimed at the formation of the discipline's competencies in accordance with the competence matrix of the OP VO.

Table № 1

Previous and subsequent disciplines aimed at the formation of competencies

№ p/p	The cipher and the name of the competence	Previous disciplines	Subsequent disciplines (groups of disciplines)
General cultural competencies			
	UK-2 The ability to design and carry out complex research, including interdisciplinary, based on a holistic systematic scientific worldview using knowledge in the field of history and philosophy of science	Methodology of scientific research	Scientific research (research activity)
General professional competencies			
	OPK-1 knowledge of the methodology of theoretical and experimental research in the field of professional activity	Methodology of scientific research	Scientific research (research activity)
Professional competencies (type of professional activity _____)			
	PK-3 The ability to independent (including managerial) research activities that require extensive fundamental training in modern areas of branch science, deep specialized training in the chosen direction, possession of skills of modern research methods	Methodology of scientific research	Scientific research (research activity)

Professional and specialized competencies of specialization _____			

3. Requirements for the results of mastering the discipline:

The process of studying the discipline is aimed at the formation of the following competencies: *UK-2, OPK-1, PK-3*

As a result of studying the discipline, the student must:

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

Be able to: freely navigate all the basic concepts, theoretical results and algorithms of control theory, formulate and solve specific applied optimization and optimal control problems.

Possess: the mathematical apparatus of the theory of optimal control.

4. The scope of the discipline and types of academic work

The total labor intensity of the discipline is ___3_____ credit units.

Type of educational work	**Total hours**	**Semester**
		3
Classroom classes (total)	**40**	40
Including:		
Lectures (L)	**20**	20
Practical exercises (PE)	**20**	20
Seminars (S)	**-**	-
Laboratory work (LW)	**-**	-
Self-education (total)	**68**	68
Control	**-**	-
Total labor intensity hrs.	**108**	108
credit units	**3**	3

5. Content of the discipline

5.1. The content of the discipline sections

Section 1 . Basic concepts of management theory

Basic concepts and principles of management. The laws of management. Classification and mathematical description of control systems. Linearization. The standard form of writing the link equation.

Section 2. Optimization problems in management processes

Calculus of variations and the Pontryagin maximum principle. The Euler equation. Solving problems for finding extremals. Checking extreme values. Phase constraints in optimal control problems. Solving problems of synthesis of optimal trajectories under phase constraints. Problems for composing Bellman equations in differential form. The solution of resource allocation problems by the method of dynamic programming. Dynamic programming.

Section 3. Typical links and structure of automatic control systems

The Laplace transform. Transfer functions. Typical links of self-propelled guns. The transfer matrix. Solving linear differential equations using Laplace transforms. Characteristics of typical links. Rules for converting structural schemes. Multidimensional automatic control systems (ACS). Determination of the characteristics of the ACS links. Transfer functions of sequentially connected

links. Transfer functions of parallel connected links. The transfer function of a closed system. Private transfer functions.

Section 4. Concepts of stability, controllability, observability, identifiability

Stability of automatic control systems. Manageability and reachability. The study of the stability of ACS. Mikhailov's criterion. Nyquist criteria. Equivalence of manageability and reachability. Observability and identifiability.

Section 5. Methods for finding the extremum

The problem of nonlinear programming. Hypersurfaces of the level. Solving nonlinear programming problems using level hypersurfaces. A necessary condition for the extremum of the differentiable function. Sufficient condition of the extremum. Criteria for positive and negative certainty of a quadratic form. The derivative in the direction. The gradient of the function and its properties. The gradient direction theorem. Gradients as normals to the level lines. The method of the fastest descent. The method of splitting the step. The problem of finding the extremum of a unimodal function. The brute force method. The method of dividing in half. The golden ratio method. The method of chords (secant). Newton's method.

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

The rule of indefinite multipliers in the problem of finding the conditional extremum of a function of two variables. A necessary condition for an extremum in a general matprogramming problem with equality-type constraints. The Lagrange multiplier method. Cone, examples of cones. Farkash's theorem. The concept of a possible direction, examples. Conditions of regularity. The Kuhn-Tucker theorem. Geometric interpretation of the Kuhn – Tucker conditions. Kuhn-Tucker conditions for equality type constraints. Maximin and minimax are functions of two variables, a lemma about the relationship between them. The concept of a saddle point. Examples of the presence and absence of saddle points. A necessary and sufficient condition for the existence of a saddle point. The concept of a dual problem, the relation of duality. The saddle point theorem of the Lagrange function. The duality theorem for linear programming problems. Smooth extremal problems in normed spaces. The Lagrange multiplier rule. Smooth problems with constraints of the type of equalities and inequalities, necessary and sufficient extremum conditions.

5.2. Sections of disciplines and types of classes

№ p/p	Name of the discipline section	L	S	PE	SRS	Total hrs.
1.	Section 1 Basic concepts of management theory	3		3	12	18
2.	Section 2. Optimization problems 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 stability, controllability, observability, identifiability	3		3	12	18
5.	Section 5. Methods for finding the extremum	4		4	10	18
6.	Section 6. Lagrange function, Kuhn-Tucker conditions and convex programming problems	4		4	10	18
	In Total	20		20	68	108

6. Laboratory workshop *is not provided*

7. Practical classes (seminars) *(if available)*

№ p/p	№ of the discipline section	Topics of practical classes (seminars)	Labor intensity (hrs.)

1.	1	Mathematical description of control systems. Linearization. The standard form of writing the link equation	1
2.	1	The Euler equation. Solving problems for finding extremals. Checking extreme values. The Pontryagin maximum principle	2
3.	1	Solving problems of synthesis of optimal trajectories using the Pontryagin principle	1
4.	2	Solving problems of synthesis of optimal trajectories under phase constraints	1
5.	2	Problems for composing Bellman equations in differential form. Dynamic programming solution of resource allocation problems	2
7.	3	Solving linear differential equations using Laplace transforms. Transfer functions and transfer matrices	1
8.	3	Determination of the characteristics of the ACS links. Transfer functions of sequentially connected links. Transfer functions of parallel connected links. The transfer function of a closed system. Private transfer functions.	1
9.	4	Stability of automatic control systems. Manageability and reachability.	1
10.	4	The study of the stability of ACS. Mikhailov's criterion. Nyquist criteria.	1
11.	4	Equivalence of manageability and reachability. Observability and identifiability.	1
12.	5	Examples of linear and nonlinear programming problems. Hypersurfaces of the level. Solving nonlinear programming problems using level hypersurfaces. A necessary condition for the extremum of the differentiable function. Sufficient condition of the extremum. Criteria for positive and negative certainty of a quadratic form.	1
13.	5	Finding derivatives in the direction. Finding the directions of the greatest increase (decrease) of functions. Gradients and normals to the level lines. The method of the fastest descent. The method of splitting the step. The Frank-Wolfe method. Coordinate descent.	1
14.	5	The problem of finding the extremum of a unimodal function. The brute force method. The method of dividing in half. The golden ratio method. The method of chords (secant). Newton's method. A modified Newton's method.	1
15.	6	The Fibonacci method. Solving mathematical programming problems with equality-type constraints.	1
16.	6	Examples of cones. Possible directions, examples. Conditions of regularity. The Kuhn-Tucker theorem. Geometric 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 for functions with two groups of variables. Dual problems of linear programming.	1
18.	6	The Euler equation. Integrals of the Euler equation. The Boltz problem. An isoparametric problem.	1
		In Total:	20

8. Material and technical support of the discipline:

Moscow, Ordzhonikidze str., 3, building 1, 5. Educational and Scientific Laboratory of Integrated Control Systems, office 350.

Main equipment: Kontar software and hardware complex-12 pcs.; computers (workstation) – 13 pcs.; Xerox Phaser 3125 printer – 1 pc.; EPSON PERFECTION V10 scanner – 1 pc.; Toshiba TLP – XC3000 projector-1 pc.; Polyvision TSL 610 interactive whiteboard – 1 pc.; floor cabinet DG – Rack 26U 600 x 800 x 1390-1 pc.; fan module for floor cabinets DG – Rack-1 pc.; Cisco Catalyst switch 2960 24 10/100 + 2T/SFP LAN Base Image + CWDM 1590 NM SFP Gigabit Ethernet and 1G/2G FC – 2 pcs.; HP DL380G5 – 2XeonE5410 server – 2 pcs.; APC Smart-UPS RT 5000VA RM 230V uninterruptible power supply unit - 2 pcs.; HP Proliant DL785G5 8356 server-1 pc.; Software:

ABBYY Finereader 9 Corporate Edition;

ABBYY Lingvo 12 European version; Adobe Acrobat 8 Professional;

Matlab 2008a;Mathcad 14.

9. Information support of the discipline

(the list of information technologies used in the implementation of the educational process in the discipline (module) is indicated, including a list of software and information reference systems (if necessary))

a) the software is used only licensed, installed in the RUDN. The Microsoft Office software package and specialized software Dev-C++, Scilab.

b) databases, information and reference and search engines _____

RSL Electronic Library http://www.rsl.ru/

Website of the RUDN Library http://lib.rudn.ru/

Science Direct http://www.sciencedirect.com Description: The resource contains a collection of scientific, technical full-text and bibliographic information. The database of a multidisciplinary nature includes scientific journals on exact and technical sciences.

EBSCO http://search.ebscohost.com, Academic Search Premier (a database of complex topics, contains information on the humanities and natural fields of knowledge).

Oxford University Press http://www3.oup.co.uk/jnls. Journals on exact and technical sciences Oxford University Press presented in the HSS collection

Sage Publications http://online.sagepub.com . The Sage publication database includes journals in various branches of knowledge: Sage_STM – more than 100 journals in the field of natural sciences, technology.

Springer/Kluwer http://www.springerlink.com. Journals and books published by Springer / Kluwer cover various fields of knowledge and are divided into subject categories.

Tailor & Francis http://www.informaworld.com . The collection of journals includes more than 1000 titles in all fields of knowledge.

American Mathematical Society http://www.ams.org/ Resource of the American Mathematical Society.

European Mathematical Society http://www.euro-math-soc.eu/ Resource of the European Mathematical Society.

Portal to Mathematics Publications http://www.emis.de/projects/EULER/

Catalog of mathematical Internet resources http://www.mathtree.ru/

Zentralblatt MATH (zbMATH) https://zbmath.org

All-Russian Mathematical portal mathnet.ru

Web of Science http://www.isiknowledge. com

Resources of the Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences (INION RAS) http://elibrary.ru.

University Information System RUSSIA. http://www.cir.ru/index.jsp.

GOST standards system of standards for information, library and publishing http://www.ifap.ru/library/gost/sibid.htm.

Electronic Library of the RUDN http://www.rsl.ru/

10. Educational and methodological support of the discipline:

a) main literature

1. Burkov. V. N., Korgin N. A., Novikov D. A. Introduction to the theory of management of organizational systems: Textbook / Edited by D. A. Novikov. - M.: Book House "LIBROCOM", 2009.
2. Vasin A. A. Research of operations: textbook. manual for university students. - M.: Academy, 2008 – - 464 p.
3. Vdovin V. M. Theory of systems and system analysis: Rec. GUU in the quality of textbooks for universities/V. M. Vdovin, L. E. Surkova, V. A. Valentinov.- 2nd ed. - Moscow: ITK "Dashkov and K", 2012 – - 638 p.
4. Moiseev N. N. Mathematical problems of system analysis. - M.: Librocom, 2012 – - 490 p.
5. Sobol B. Ch., Meskhi G. I., Kanygin B. V. Optimization methods: Practicum . - Rostov on Don: Phoenix, 2009.

б) additional literature

6. Alekseev V. M., Galeev E. M., Tikhomirov V. M. Collection of optimization problems. - Moscow: FIZMATLIT, 2005 – - 256 p.
7. Evmenov V. P. Intelligent control systems. - M.: LIBROKOM, 2009 – - 304 p..
8. Esipov B. A. Methods of operations research-St. Petersburg: Lan, 2010.
9. Kornienko V. P. Optimization methods. Approved by the UMS in Applied Mathematics and Computer Science of the UMO as a textbook for university students in the specialty "Applied Mathematics and Computer Science". - Moscow: HIGHER SCHOOL, 2007. - 664 p.
10. Miroshnik I. V. Theory of automatic control. Linear systems. Peter, 2005.
11. Panteleev A.V., Bortakovsky A. S. Control theory in examples and problems. - M., Higher School, 2003.
12. Sukharev A. G., Timokhov A.V., Fedorov V. V. Course of optimization methods. - Moscow: Moscow, FIZMATLIT, 2005.

11. Methodological guidelines for students on the development of the discipline (module)

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

While studying the discipline, the student must attend a course of lectures, pass the number of seminars provided for by the work program, independently study some topics of the course and confirm their knowledge during control events.

The student's work at the lecture consists in understanding the basics of the discipline, briefly taking notes of the material, clarifying issues that cause difficulties. The lecture notes are the basic educational material along with the textbooks recommended in the main list of references.

The main part of the lecture material is taught using multimedia tools that facilitate the perception and memorization of the material. The presentations are available for download from the RUDN website and can be freely used by students for educational purposes.

The student is obliged to master all the topics provided for by the educational and thematic plan of the discipline. Individual topics and training issues are submitted for independent study. The student studies the recommended literature and briefly outlines the material, and clarifies the most difficult questions that require clarification during consultations. The same should be done with the sections of the course that were skipped due to various circumstances.

For an in-depth study of the issue, the student should familiarize himself with the literature from the additional list and specialized websites on the Internet. It is also recommended that students communicate on the forums of professional communities.

Students independently study educational, 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 at seminars, as well as at lectures, asking clarifying questions to the lecturer.

The control of the independent work of the masters is carried out by the leading teacher. Depending on the teaching methodology, the following forms of current control can be used: a short oral or written survey before the start of classes, written homework, essays, etc..

12. Fund of evaluation funds for conducting intermediate certification of students in the discipline (module)

Materials for assessing the level of mastering the educational material of the discipline " Applied Methods of the Numerical Solutions of Optimal Control Problems " (evaluation materials), including a list of competencies indicating the stages of their formation, a description of indicators and criteria for evaluating competencies at various stages of their formation, a description of evaluation scales, standard control tasks or other materials necessary for evaluating knowledge, skills, skills and (or) experience of activity that characterize the stages of competence formation in the process of mastering the educational program, methodological materials, the defining procedures for assessing knowledge, skills, skills and (or) experience of activity that characterize the stages of competence formation are fully developed and are available to students on the discipline page in the TUIS RUDN.

The program is compiled in accordance with the requirements of the OS VO RUDN.

Developers:

_____Ph.D._____	_____	___O.A.Saltykova___
position, name of the department	signature	initials, surname

Program manager

_____Prof._____	_____	_____Yu.N.Razoumny__
position, name of the department	signature	initials, surname