Federal State Autonomous Educational Institution
higher education
RUDN University

Academy of Engineering

Recommended by the MCSD

THE WORKING PROGRAM OF THE DISCIPLINE

Discipline name: Additional Topics of Theoretical Mechanics and Mechanics of Space Flight

Direction of training: 01 .06.01 " Mathematics and Mechanics "

Directivity (profile): " Dynamics, ballistics, movement control of aircraft "

Moscow,
2021

1. The purpose and objectives of the discipline

The purpose of mastering the discipline "Additional sections of theoretical mechanics and mechanics of space flight" is to form a system of scientific knowledge among graduate students about promising research methods and solving professional problems, taking into account world trends in the development of aviation and rocket-space technology.

The main **objectives** of the discipline are:

- Know new methods of development and research of methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket and space technology
- Master new methods of selection and transformation of mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study and implement them by means of computer technology
- Be able to use new methods of developing mathematical models, methods, computer technologies and decision support systems in scientific research, design and development activities, management of technological, economic, social systems and in the humanitarian areas of human activity

2. Place of discipline in the structure of the educational program

The discipline "Additional sections of theoretical mechanics and mechanics of space flight" refers to the variable part of Block 1 of the curriculum. Its study is based on the material of previous disciplines, and it is also basic for the study of subsequent disciplines of the curriculum, the list of which is presented in table 1.

Table 1 - List of previous and subsequent disciplines

№ i/o	Cipher and name of competence	Previous disciplines/practices	Subsequent disciplines
Universal competencies			
	ability to critical analysis and assessment modern scientific achievements, generating new ideas in solving research and practical problems, including in interdisciplinary fields (UC-1)	History and Phylosophy of Science Methodology of Scientific Research	
General professional competencies			
Professional competencies (type of professional activity _____)			
	the readiness to apply promising research methods and solve professional problems, taking into account the world trends in the development of aviation	Methodology of Scientific Research	

	and rocket and space technology (PC-1)		
	the ability to create and research mathematical and software models of products and processes associated with the functioning of objects of aviation and rocket technology (PC-2)	Methodology of Scientific Research	
	readiness to develop and research methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology (PC-3)	Methodology of Scientific Research Priority Directions of Development of Mathematics and Mechanics	
	the ability to select and transform mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study them (PC-4)	Fundamentals of Teaching Methods of Development of Engineering Applications Based on Mathematical Modeling Using Computer Science and Computer Technology in high school	
	the ability to develop mathematical models, methods, computer technologies and decision support systems in scientific research, design and engineering activities (PC-5)	Fundamentals of Teaching Methods of Development of Engineering Applications Based on Mathematical Modeling Using Computer Science and Computer Technology in high school	
	the ability to develop new mathematical models of objects of aviation and rocket-space technology, to develop analytical and approximate research methods (PC-6).	Priority Directions of Development of Mathematics and Mechanics Fundamentals of Teaching Methods of Development of Engineering Applications Based on Mathematical Modeling Using Computer Science and Computer	

		Technology in high school	
Профессионально-специализированные компетенции специализации			

3. The list of planned learning outcomes in the discipline, correlated with the planned results of mastering the educational program

The discipline "Additional sections of theoretical mechanics and mechanics of space flight " is aimed at developing the following competencies among students:

- Ability to critically analyze and evaluate modern scientific achievements, generate new ideas in solving research and practical problems, including in interdisciplinary areas;
- Ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies
- Willingness to apply promising research methods and solve professional problems, taking into account world trends in the development of aviation and rocket and space technology;
- Ability to create and research mathematical and software models of products and processes associated with the operation of objects of aviation and rocket technology;
- Willingness to develop and research methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology;
- Ability to select and transform mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study them;
- Ability to develop mathematical models, methods, computer technologies and decision support systems in scientific research, design and engineering activities;
- Ability to develop new mathematical models of objects of aviation and rocket-space technology, to develop analytical and approximate research methods.

The result of training in the discipline is knowledge, abilities, skills and (or) experience of activities that characterize the stages of the formation of competencies and ensure the achievement of the planned results of mastering the educational program, presented in Table 2.

Table 2 - Learning outcomes in the discipline correlated with the planned results of mastering

Competence	**Knowledge**	**Skills**	**Skills**
1	2	3	4
Ability to critically analyze and evaluate modern scientific achievements, generate new ideas when solving research and practical problems, including in interdisciplinary areas	Know the methods of critical analysis and assessment of modern scientific achievements, as well as methods of generating new ideas when solving research and practical problems,	To be able, when solving research and practical problems, to generate new ideas that can be operationalized based on available resources and constraints	Possess the skills of analyzing methodological problems arising in the solution of research and practical problems, including in the interdisciplinary field

	including in interdisciplinary fields		
Ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies	Know the development plan of the scientific organization, the activity plan of the unit, data on competitions for the financing of scientific activities	Be able to select competitions for funding scientific activities	Own the directions and tasks of the unit for the implementation of the strategic development plan of the organization, the formation of proposals on research topics
Willingness to apply promising research methods and solving professional problems, taking into account world trends in the development of aviation and rocket and space technology	Know the methods of research and solving professional problems, taking into account the world trends in the development of aviation and rocket and space technology.	To be able to apply research methods and solving professional problems, taking into account the world trends in the development of aviation and rocket and space technology.	Possess promising methods of research and solving professional problems, taking into account world trends in the development of aviation and rocket and space technology.
Ability to create and research mathematical and software models of products and processes associated with the functioning of objects of aviation and rocket technology	Know new methods of creating and researching mathematical and software models of products and processes associated with the functioning of objects of aviation rocket technology	To be able to use new methods of creating and researching mathematical and software models of products and processes associated with the functioning of objects of aviation missile technology	Possess new methods of creating and researching mathematical and software models of products and processes associated with the functioning of objects of aviation and missile technology
Willingness to develop and research methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology	Know new methods of development and research of methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology	To be able to use new methods of development and research of methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology	Possess new methods of development and research of methods of analysis, synthesis, optimization and forecasting of the quality of the processes of functioning of aviation and rocket technology
The ability to select and transform mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study them	Know new methods of selection and transformation of mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study them	To be able to use new methods of selection and transformation of mathematical models of phenomena, processes and systems in the field of rocket and space	Possess new methods of choosing and transforming mathematical models of phenomena, processes and systems in the field of rocket and space technology in order to study them

		technology in order to study them	
Ability to develop mathematical models, methods, computer technologies and decision support systems in scientific research, design and engineering activities	Know new methods of developing mathematical models, methods, computer technologies and decision support systems in scientific research	Be able to use new methods for the development of mathematical models, methods, computer technologies and decision support systems in scientific research	Possess new methods of developing mathematical models, methods, computer technologies and decision support systems in scientific research
Ability to develop new mathematical models of objects of aviation and rocket and space technology, to develop analytical and approximate research methods	Know new methods of developing mathematical models of objects of aviation and rocket-space technology	Be able to use new methods for the development of mathematical models of objects of aviation and rocket and space technology	Own new methods for the development of mathematical models of objects of aviation and rocket-space technology

4. Scope of discipline and types of educational work

Table 3 - Scope of discipline and types of educational work
for full-time education

Type of educational work		Total, ac. hours	Semester
			four
Auditory lessons		twenty	twenty
including:		-	-
Lectures (L)		-	-
Practical / Seminar Lessons (PZ)		twenty	twenty
Laboratory work (LR)		-	-
Course project / course work		-	-
Independent work (IWS), including control		88	88
Type of certification test			Exam
Total labor intensity	academic hours	108	108
	credit units	3	3

5. Content of the discipline

Table 4 - Content of the discipline and types of classes
for full-time education

P / p No.	Name of the discipline section / topic of the lesson	Practice. / workshop.	CPC	Total
hour.				
one.	Section 1. Classification of tasks and methods of aircraft motion control	2	10	12
	Topic 1.1. Classification of tasks and methods of aircraft motion control	2	10	12

P / p No.	Name of the discipline section / topic of the lesson	Practice. / workshop.	CPC	Total
2.	Section 2. Technical problem of aircraft entry into an orbital constellation and its mathematical formalization	2	sixteen	eighteen
	Topic 2.1. Formulation of the technical problem of aircraft entry into the orbital constellation and its mathematical formalization	2	sixteen	eighteen
3.	Section 3. Mathematical models of controlled aircraft motion	four	eighteen	22
	Topic 3.1. Coordinate systems for calculating the aircraft motion Newton's equations. Equations in osculating elements	one	6	7
	Topic 3.2. Equations in Equinoxes. Equations in a spherical system	one	6	7
	Topic 3.3. Linearization of the equations of motion in various coordinate systems. Discrete motion model	2	6	eight
4 .	Section No. 4. Optimal control of the aircraft motion during additional placement into geostationary orbit	6	twenty	26
	Topic 4 .1. Statement of the problem of launching an aircraft to the GSO using the upper stage. Reduction to a nonlinear programming problem	2	6	eight
	Topic 4 .2. Launching the aircraft to the GSO with a low-thrust engine	2	6	eight
	Topic 4 .3. Launching the aircraft GSO using EPP, taking into account the shadow areas	2	eight	10
5 .	Section 5. Optimal control of the aircraft's motion when entering and holding an orbital position	6	twenty	26
	Topic 5 .1. Mathematical model of motion when the aircraft is put into the orbital position in the GSO	one	five	6
	Topic 5 .2. Combined optimization method. Software and synthesized control components	one	five	6
	Topic 5 .3. Algorithm for searching for a synthesized component. The concept of suboptimal control. Algorithm for searching the software component	2	five	7
	Topic 5 . 4 . Software implementation of aircraft control algorithms	2	five	7

6. Educational technology

The organization of classes in the discipline "Additional sections of theoretical mechanics and mechanics of space flight" is carried out in the following types of educational work: interactive practical classes (seminars), preparation of independent work and subsequent defense.

The implementation of the competence-based approach in the framework of the training area 01.06.01 "Mathematics and Mechanics" provides for a combination in the educational process of contact work with a teacher and extracurricular independent work of students for a more complete formation and development of his professional skills, independent study of some topics of the course and confirmation of their knowledge during control measures.

The graduate student is obliged to master all the topics provided for by the curriculum of the discipline. Certain topics and issues of training are designed for independent study. The postgraduate student covers the recommended literature and briefly notes the material and clarifies the most difficult issues requiring clarification during tutorials. The same should be done with sections of the course that were skipped due to various circumstances.

The purpose of practical classes and seminars is to obtain knowledge and practical skills for graduate students in the field of ballistics and navigation of launch vehicles. To achieve these goals, both traditional forms of work are used - solving problems, working with technological equipment / specialized software when performing laboratory work, etc., as well as interactive methods - group work, analysis of specific situations, etc.

Using the method of analyzing a specific situation, students develop such skills as the ability to clearly formulate and express their position, the ability to communicate, discuss, perceive and evaluate information received in verbal form. Practical classes and seminars are held in special classrooms equipped with the necessary visual aids.

Independent work covers the study of individual questions of the theoretical course by students.

Independent work is carried out in an individual format based on the teaching materials of the discipline (*Appendices 2-4*). The level of mastering the material on independently studied issues of the course is checked during current control and certification tests (exam and / or test) in the discipline.

7. Educational-methodical and informational support of the discipline

Main literature:

1. Ed. Byushgens G.S. Flight dynamics. M .: Mashinostroenie, 2011 .-- 776 p.
2. Statistical dynamics and optimization of aircraft control Textbook for universities / Under the general editorship of M. N. Krasil'shchikov, V. V. Malysheva / 2nd ed. revised and add. - M .: Alliance, 2013 .- 468 p., Illustrated.
3. Fedorov A.V. Collection of assignments for term paper in the discipline "Optimal aircraft control", MAI, department. 604, 2012
4. Malyshev V.V. Optimization methods in problems of system analysis and management textbook. manual for universities of the Russian Federation on specials. 160703 "Flight dynamics and aircraft motion control" direction. 160700 "Hydroaerodynamics and flight dynamics" and special. 23031 "Modeling and research of operations in organizational and technical systems" direction. 230300 "Organizational and technical systems". MAI-PRINT, 2010 .- 440 p.

Additional literature:

1. Alekseev K.B., Bybenin G.G., Yaroshevsky V.A. Spacecraft maneuvering. - Moscow: Mechanical Engineering, 1970 .-- 232 p.
2. Fedorov A.V. Solving mathematical programming problems in the Delphi environment. Problems of unconstrained minimization of functions. MAI department 606, 2014
3. Fedorov A.V. Programming tasks for modeling complex systems in the Delphi

environment. Simulate + class library. MAI, dept. 604, 2012.
4. Fedorov A.V. Simulate + / Space class library. Simulation of spacecraft motion. MAI department 606, 2014.
5. Malyshev V.V. Optimization methods in problems of system analysis and control: Textbook. — M .: Publishing house MAI-PRINT, 2010. - 440p.: illustrated.

Resources of the information and telecommunications network "Internet":

1. Electronic library system (ELS) of RUDN University and third-party ELS to which university students have access on the basis of concluded agreements:

- RUDN University Electronic Library System - RUDN University Library System http://lib.rudn.ru/MegaPro/Web
- ELS "University Library Online" http://www.biblioclub.ru
- ELS Yurayt http://www.biblio-online.ru
- ELS "Student Consultant" www.studentlibrary.ru
- ELS "Lan" http://e.lanbook.com/

2. Websites of ministries, departments, services, manufacturing enterprises and companies whose activities are core to this discipline:

3. Databases and search engines:

- electronic fund of legal and normative-technical 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/

Methodological materials for independent work of students and the study of the discipline (also posted in the TUIS RUDN in the corresponding section of the discipline):

1. A course of lectures on the discipline "Additional sections of theoretical mechanics and mechanics of space flight" (*Appendix 2*).
2. Methodical instructions for independent work of students in the discipline "Additional sections of theoretical mechanics and mechanics of space flight" (*Appendix 3*).

8. Material support of the discipline

Table 5 – Material support of the discipline

Auditorium with material support list	**Location**
Educational laboratory "Laboratory of computing systems and methods of processing big data": № 409 Equipment and furniture: - Personal graphic workstations based on the AVK-1 system unit + monitor (13 pcs.); – Interactive whiteboard Polyvision TSL 610; – Epson EB-X02 projector; – Switch Cisco Catalyst 2960 24; – Line filter. There is Internet access. – List of licensed software. Details of the supporting document:	г. Москва, ул. Орджоникидзе, д. 3

1. Windows 7 (Microsoft Subscription) Enrollment for Education Solutions No. 86626883 dated 01.04.2018); 2. Microsoft Office 2007 (Microsoft Subscription) Enrollment for Education Solutions No. 86626883 dated 04/01/2018); 3. Borland Developer Studio 2006 (License Certificate Number: 33080, 33081, 33082); 4. MATLAB R2008b (361405 2008); 5. Notepad ++ (free use). 6. Acrobat Reader DC (free use)	

9. Set of assessment tools

The set of assessment tools, established for the continuous assessment of progress and midterm assessment of students in the discipline "Additional sections of theoretical mechanics and mechanics of space flight" is presented in *Appendix 1* to the work program of the discipline and includes:

- a list of competencies with an indication of the stages of their formation in the process of mastering the educational program;
- description of indicators and criteria for assessing competencies at various stages of their formation, description of assessment scales;
- typical control tasks or other materials necessary to assess knowledge, skills, skills and (or) experience of activity, characterizing the stages of the formation of competencies in the process of mastering the educational program;
- methodological materials defining the procedures for assessing knowledge, skills, skills and (or) experience of activities, characterizing the stages of the formation of competencies.

Developers:

Associate Professor of the Department of Mechanics and Mechatronics — position — O. E. Samusenko — initials, surname

Senior Lecturer of the Department of Mechanics and Mechatronics — position — T. A. Morozova — initials, surname

Supervisor of the Master Program
Professor of the Department of Mechanics and Mechatronics — Yu.N. Razumny

Director of the Department of Mechanics and Mechatronics — signature — Yu. N. Razumny — initials, surname