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

Academy of Engineering

Recommended by the ISSC

THE WORKING PROGRAM OF THE DISCIPLINE

Discipline Name: Mathematical foundations of ballistic support of spacecraft 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 goal of mastering the discipline "Mathematical foundations of ballistic support for spacecraft 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 and space technology.

The main objectives of the discipline are:

 Know new methods of development and research of mathematical models for ballistic support of spacecraft flight

 Own new methods of selection and transformation of mathematical models of phenomena, processes and systems in the field of rocket and space technology for the purpose of their research and implementation 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 "Mathematical foundations of ballistic support for spacecraft flight" refers to the disciplines of choosing 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

№ п/п	Code and name of competence	Previous disciplines	Subsequent disciplines (groups of disciplines)
Universal competences			
	Ability to critically analyze and evaluate modern scientific achievements, generate new ideas in solving research and practical problems, including in interdisciplinary fields (UK-1)	History and philosophy of science	
General professional competencies			
Professional competencies (type of professional activity _____)			
	Willingness to apply promising research methods and solve professional problems, taking into account global trends in the development of aviation and rocket and space technology (PC-1);	Research methodology	

	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);	Research methodology	
	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 (PC-3);		
	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);	Research methodology	
	Ability to develop mathematical models, methods, computer technologies and decision support systems in scientific research, design and engineering activities (PC-5);	Priority areas for the development of mathematics and mechanics	
	Ability to develop new mathematical models of objects of aviation and rocket and space technology, to develop analytical and approximate research methods (PC-6).	Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using computer science and computer technology in higher education	
Vocational 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-1, PC-1, PC-2, PC-3, PC-4, PC-5, PC-6*

(indicated in accordance with the ES of HE of RUDN University)

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

Know:

- - 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, including in interdisciplinary fields

- - Know the development plan of the scientific organization, the activity plan of the unit, data on competitions for financing scientific activities
- - 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.
- - Know new methods of creating and researching mathematical and software models of products and processes associated with the functioning of objects of aviation missile 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
- - 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
- - Know new methods of developing mathematical models, methods, computer technologies and decision support systems in scientific research

- Know new methods for the development of mathematical models of objects of aviation and rocket-space technology

Be able to:

- To be able, while solving research and practical problems, to generate new ideas that can be operationalized based on available resources and constraints
- Be able to select competitions for funding scientific activities
- 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.
- 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 and missile 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
- 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 technology in order to study them
- Be able to use 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 of objects of aviation and rocket-space technology

Own:

- Possess the skills of analyzing methodological problems arising in the solution of research and practical problems, including in the interdisciplinary field
- 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
- Possess promising methods of research and solving professional problems, taking into account world trends in the development of aviation and rocket and space technology.
- Possess new methods of creating and researching mathematical and software models of products and processes associated with the operation of objects of aviation and missile 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
- Possess 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

- Possess new methods of developing mathematical models, methods, computer technologies and decision support systems in scientific research
- Possess new methods for the development of mathematical models of objects of aviation and rocket-space technology

4. Объем дисциплины и виды учебной работы

Общая трудоемкость дисциплины составляет 3 зачетных единицы.

Type of educational work		Total, ac. hours	Term
			3
Auditory lessons		20	20
including:		-	-
Lectures (L)		-	-
Practical / Seminar Lessons (PZ)		20	20
Laboratory work (LR)		-	-
Course project / course work		-	-
Independent work (IWS), including control		88	88
Type of certification test			Exam
Total workload of	academic hours	108	Total workload of
	credit units	3	3

5. Content of the discipline

5.1. Contents of discipline sections

№ п/п	The name of the discipline section	Section content (topics)
1.	1. Coordinate systems and methods of their transformation	1.1. Goals and objectives of dynamic and ballistic flight support. Mathematical foundations. Coordinate systems, their classification
2	2. Forces and moments acting on the aircraft in flight	2.1. Classification of forces acting on the aircraft. Gravity and its potential. Engine thrust. Aerodynamic forces and moments. Aerodynamic coefficients 2.2. Types of aircraft motion models. Solidification principle. Transportable and Coriolis forces. Inertia tensor 2.3. Characteristics of various sections of aircraft trajectories. The concept of different types of aircraft movements. Simplification methods for aircraft movement models and their correspondence to the site
3	3. Vector-matrix representations of the equations of aircraft motion	3.1. Aircraft motion model taking into account elastic vibrations of its body and other structural elements 3.2. Features of simplification of aircraft movement models in different traffic areas. Relationship between the simplification method and the nature of the site
4	4. Systems of scalar differential equations of space motion of aircraft	4.1. Characteristics of the spatial movements of the aircraft. Methods and features of motion modeling. The nature of the change in variables for different types of aircraft 4.2. Subdivision of the equations of aircraft motion into dynamic and kinematic. Features of each group and their simplifications 4.3. Tasks and methods of research of mathematical models of aircraft motion. Various models and their features. Relationship between the motion model and the problem statement 4.4. Atmosphere of the Earth. Composition and properties. Standard atmosphere. Taking into account the characteristics of the real atmosphere. Earth's magnetic field and its mathematical

		description
5	5. Indignant aircraft movement and general characteristics of its research methods	5.1. Outraged aircraft movement. General characteristics of tasks and methods for their solution. 5.2. Linearization as a method for obtaining a model of disturbed motion. Various types of linearization. Assessment of the applicability of the method 5.3. Application of frequency methods to analyze the dynamic properties of aircraft A. Transfer functions and frequency characteristics of aircraft A. Indicators of dynamic properties of aircraft

5.2. Разделы дисциплин и виды занятий

№ п/п	The name of the section of the discipline / topic of the lesson.	Pract. / workshop	CPC	Total hour.
1.	**Section # 1. Coordinate systems and methods of their transformation**	**2**	**8**	**10**
	Topic 1.1. Goals and objectives of dynamic and ballistic flight support. Mathematical foundations. Coordinate systems, their classification	2	8	10
2.	**Section # 2. Forces and moments acting on the aircraft in flight**	**2**	**20**	**22**
	Topic 2.1. Classification of forces acting on the aircraft. Gravity and its potential. Engine thrust. Aerodynamic forces and moments. Aerodynamic coefficients.	0,5	4	4,5
	Topic 2.2. Types of aircraft motion models. Solidification principle. Transportable and Coriolis forces. Inertia tensor.	0,5	8	8,5
	Topic 2.3. Characteristics of various sections of aircraft trajectories. The concept of different types of aircraft movements. Simplification methods for aircraft movement models and their correspondence to the site	1	8	9
3.	**Section # 3. Vector-matrix representations of the equations of aircraft motion**	**4**	**20**	**24**
	Topic 3.1. Aircraft motion model taking into account elastic vibrations of its body and other structural elements	2	10	12
	Topic 3.2. Features of simplification of aircraft movement models in different traffic areas. Relationship between the simplification method and the nature of the site	2	10	12
4	**Section No. 4. Systems of scalar differential equations of space motion of aircraft**	**6**	**20**	**26**
	Topic 4.1. Characteristics of the spatial movements of the aircraft. Methods and features of motion modeling. The nature of the change in variables for different types of aircraft	1	4	5
	Topic 4.2. Subdivision of the equations of aircraft motion into dynamic and kinematic.	1	4	5

№ п/п	The name of the section of the discipline / topic of the lesson.	Pract. / workshop	CPC	Total hour.
	Features of each group and their simplifications			
	Topic 4.3. Tasks and methods of research of mathematical models of aircraft motion. Various models and their features. Relationship between the motion model and the problem statement	2	6	8
	Topic 4.4. Atmosphere of the Earth. Composition and properties. Standard atmosphere. Taking into account the characteristics of the real atmosphere. Earth's magnetic field and its mathematical description	2	6	8
5	**Section # 5. Indignant aircraft movement and general characteristics of the methods of its research**	**6**	**20**	**26**
	Topic 5.1. Outraged aircraft movement. General characteristics of tasks and methods of their solution	2	6	8
	Topic 5.2. Linearization as a method for obtaining a model of perturbed motion. Various types of linearization. Assessment of the applicability of the method	2	6	8
	Topic 5.3. Application of frequency methods for the analysis of the dynamic properties of aircraft. Transfer functions and frequency characteristics of aircraft. Indicators of dynamic properties of aircraft	2	8	10
	Exam	**20**	**88**	**108**

6. Laboratory workshop (if any) - not provided

7. Practical lessons (seminars) (if any)

№ п/п	No. of discipline section	Topic of practical classes (seminars)	Labor capacity
1.	**1**	Topic 1.1. Goals and objectives of dynamic and ballistic flight support. Mathematical foundations. Coordinate systems, their classification	2
2	**2**	Topic 2.1. Classification of forces acting on the aircraft. Gravity and its potential. Engine thrust. Aerodynamic forces and moments. Aerodynamic coefficients.	0,5
3	**2**	Topic 2.2. Types of aircraft motion models. Solidification principle. Transportable and Coriolis forces. Inertia tensor.	0,5
4	**2**	Topic 2.3. Characteristics of various sections of aircraft trajectories. The concept of different types of aircraft movements. Simplification methods for aircraft movement models and their correspondence to the site	1
5	**3**	Topic 3.1. Aircraft motion model taking into account elastic vibrations of its body and other structural elements	2
6	**3**	Topic 3.2. Features of simplification of aircraft movement	2

		models in different traffic areas. Relationship between the simplification method and the nature of the site	
7	**4**	Topic 4.1. Characteristics of the spatial movements of the aircraft. Methods and features of motion modeling. The nature of the change in variables for different types of aircraft	1
8	**4**	Topic 4.2. Subdivision of the equations of aircraft motion into dynamic and kinematic. Features of each group and their simplifications	1
9	**4**	Topic 4.3. Tasks and methods of research of mathematical models of aircraft motion. Various models and their features. Relationship between the motion model and the problem statement	2
10	**4**	Topic 4.4. Atmosphere of the Earth. Composition and properties. Standard atmosphere. Taking into account the characteristics of the real atmosphere. Earth's magnetic field and its mathematical description	2
11	**5**	Topic 5.1. Outraged aircraft movement. General characteristics of tasks and methods of their solution	2
12	**5**	Topic 5.2. Linearization as a method for obtaining a model of perturbed motion. Various types of linearization. Assessment of the applicability of the method	2
13	**5**	Topic 5.3. Application of frequency methods for the analysis of the dynamic properties of aircraft. Transfer functions and frequency characteristics of aircraft. Indicators of dynamic properties of aircraft	2

8. Logistics of the discipline

Table 5 - Material and technical support of the discipline

Auditorium with a list of logistics	**Location**
Educational laboratory "Laboratory of computing systems and methods of processing big data": No. 345 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: 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 application).	Moscow, Ordzhonikidze st, 3

1. 6. Acrobat Reader DC (free application)	

9. Information support of the discipline

Resources of the information and telecommunications network "Internet":

1. EBS of RUDN University and third-party EBS to which university students have access on the basis of concluded agreements:

- Electronic library system RUDN - EBS RUDN http://lib.rudn.ru/MegaPro/Web
- EBS "University Library Online" http://www.biblioclub.ru
- EBS Yurayt http://www.biblio-online.ru
- EBS "Student Consultant" www.studentlibrary.ru
- EBS "Doe" 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 "Mathematical foundations of ballistic support for spacecraft flight" (Appendix 2).
2. Methodical instructions for independent work of students in the discipline "Mathematical foundations of ballistic support of spacecraft flight" (Appendix 3).

10. Educational and methodological support of the discipline

Main literature:

1. Ed. Byushgens G.S. Flight dynamics. M .: Mashinostroenie, 2011 .-- 776 p.

2. Mechanics of space flight. Ed. acad. Mishina V.P. - M.: Mechanical Engineering, 1989.

3. Lysenko L.N. Ballistic missile guidance and navigation. - M: Publishing house of MSTU im. N.E Bauman, 2007, 670s.

4. Dmirievsky A.A., Lysenko L.N. External ballistics. 4th edition. - M: Mechanical Engineering, 2005.

5. Ivanov N.M., Lysenko L.N. Ballistics and spacecraft navigation. 2nd edition. - M: Bustard, 2004.

Additional literature:

1. Alekseev K.B., Bybenin G.G., Yaroshevsky V.A. Spacecraft maneuvering. - Moscow: Mechanical Engineering, 1970 .-- 232 p.
2. Elyasberg PE Introduction to the theory of flight of artificial earth satellites. - Moscow: Nauka, 1965 .-- 540 p.
3. Himmelblau D. Applied nonlinear programming. - Moscow: Mir, 1975 .-- 534 p.
4. Herrick S. Astrodynamics. - Moscow: Mir, 1978 .-- 359p.

5. Sikharulidze Yu.G. Aircraft ballistics. - Moscow: Nauka, Main edition of physical and mathematical literature, 1982 .-- 352 p.
6. Reshetnev MF, Lebedev AA, Bartenev VA, Krasil'shchikov MN, Malyshev VA, Malyshev VA, Control and navigation of artificial earth satellites in near-circular orbits. - Moscow: Mechanical Engineering, 1988.336s.
7. Soloviev Ts.V., Tarasov E.V. Prediction of interplanetary flights. - Moscow: Mechanical Engineering, 1973 .-- 400 p.

11. Методические указания для обучающихся по освоению дисциплины (модуля)

The organization of classes in the discipline "Mathematical foundations of ballistic support of spacecraft flight" is carried out in the following types of educational work: interactive practical classes (seminars), preparation of independent work and their subsequent protection.
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 postgraduate student is obliged to master all the topics provided for by the curriculum of the discipline. Certain topics and issues of training are submitted for independent study. The postgraduate student studies the recommended literature and briefly notes the material, and clarifies the most difficult issues requiring clarification during consultations. 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 qualifications 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.

12. Fund of assessment tools for intermediate certification of students in the discipline (module)

The fund of assessment tools, formed for the current monitoring of progress and intermediate certification of students in the discipline "Mathematical foundations of ballistic support for spacecraft 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 that determine the procedures for assessing knowledge, skills, skills and (or) experience of activities, characterizing the stages of the formation of competencies.

The program has been drawn up in accordance with the requirements of the ES of HE RUDN University

Developers:

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