Federal State Autonomous Educational Institution of Higher Education
"Russian Peoples' Friendship University named after Patrice Lumumba"

Engineering Academy
(name of the main educational unit (POU) - developer of the EP HE)

DISCIPLINE WORK PROGRAM

DYNAMICS AND CONTROL OF SPACE SYSTEMS
(name of discipline/module)

Recommended by MSSN for the following areas of training/specialty:

01.04.02 APPLIED MATHEMATICS AND INFORMATION SCIENCE
(code and name of the area of training/specialty)

The discipline is mastered as part of the implementation of the main professional educational program of higher education (OP HE):

BALLISTIC DESIGN OF SPACE COMPLEXES AND SYSTEMS
(name (profile/specialization) EP HE)

2024G.

1. GOAL OF DISCIPLINE MASTERING

The discipline “Dynamics and Control of Space Systems” is included in the master’s program “Ballistic design of space complexes and systems” in the direction 01.04.02 “Applied mathematics and computer science” and is studied in the 3rd and 4th semesters of the 2nd year. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 3 sections and 12 topics and is aimed at studying the fundamental principles of spacecraft orbital maneuvering, methods for calculating and optimizing it, which characterize the stages of the formation of competencies, and ensure achievement of the planned results of mastering the educational program.

The goal of mastering the discipline is practical skills acquisition in solving design problems of the motion of spacecraft and various orbital structures formation and calculation, solving specific engineering problems connected with orbital launching and maneuvering, applying mathematical modeling methods in solving the set tasks using modern software tools.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline “Dynamics and control of space systems” is aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies formed in students when mastering the discipline (results of mastering the discipline)

Cipher	**Competence**	**Indicators of Competency Achievement** (within this discipline)
UK-1	Able to critically analyze problem situations based on a systematic approach and develop an action strategy	UK-1.1 Analyzes the task, highlighting its basic components;; UK-1.2 Identifies and ranks the information required to solve the task;; UK-1.3 Searches for information to solve a given problem using various types of requests;; UK-1.4 Offers options for solving a problem, analyzes the possible consequences of their use;;
UK-2	Able to manage a project at all stages of its life cycle	UK-2.1 Formulates a problem, the solution of which is directly related to achieving the project goal;; UK-2.2 Determines the connections between the assigned tasks and the expected results of their solution;; UK-2.3 Within the framework of the assigned tasks, determines the available resources and limitations, current legal norms;; UK-2.4 Analyzes the project implementation schedule as a whole and selects the optimal way to solve the assigned tasks, based on current legal norms and available resources and limitations;; UK-2.5 Monitors the progress of the project, adjusts the schedule in accordance with the results of control.;
OPK-2	Able to improve and implement new mathematical methods for solving applied problems	GPC-2.1 Uses the results of applied mathematics to master and adapt new methods for solving problems in the field of professional interests;; OPK-2.2 Implements and improves new methods for solving applied problems in the field of professional activity;; OPK-2.3 Conducts qualitative and quantitative analysis of the resulting solution in order to construct the optimal option.;
OPK-3	Able to develop mathematical models and analyze them when solving problems in the field of professional activity	OPK-3.1 Develops mathematical models in the field of applied mathematics and computer science;; OPK-3.2 Analyzes mathematical models for solving applied problems of professional activity;; GPC-3.3 Develops and analyzes new mathematical models for solving applied problems of professional activity in the field of applied mathematics and computer science.;

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
PC-1	Able to formulate goals and objectives of scientific research in the field of applied mathematics and computer science, computer technology and modern programming technologies, select methods and means for solving problems	PC-1.1 Has fundamental knowledge acquired in the field of mathematical and (or) natural sciences, programming and information technology;; PC-1.2 Can find, formulate and solve standard problems in their own research activities in the field of applied mathematics and computer science, computer technology and modern programming technologies;; PC-1.3 Has practical experience in research activities in the field of applied mathematics and computer science, computer technology and modern programming technologies.;
PK-3	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and spacecraft flight control	PC-3.1 Knows basic mathematical methods and modern tools in the field of ballistic design of space complexes and systems;; PC-3.2 Has basic knowledge of standards, norms and rules for the development of design solutions in the field of ballistics, dynamics and spacecraft flight control;; PC-3.3 Able to apply mathematical methods and modern information technologies when conducting scientific research and developing design solutions in the field of ballistics, dynamics and spacecraft flight control.;
PK-5	Able to analyze, including in English, methods for studying ballistic and dynamic characteristics when modeling spacecraft flight trajectories	PC-5.1 Knows proven and applied techniques, including from English-language sources, for studying ballistic and dynamic characteristics when modeling spacecraft flight trajectories;; PC-5.2 Able to develop and modernize methods for studying ballistic and dynamic characteristics when modeling spacecraft flight trajectories;; PC-5.3 Proficient in methods and approaches to the study of ballistic and dynamic characteristics when modeling spacecraft flight trajectories;

3. PLACE OF DISCIPLINE IN THE STRUCTURE OF HE EP

Discipline "Dynamics and control of space systems" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the educational program of higher education, students also master other disciplines and/or practices that contribute to achieving the planned results of mastering the discipline “Dynamics and Control of Space Systems.”

Table 3.1. List of components of EP HE that contribute to achieving the planned results of mastering the discipline

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
UK-2	Able to manage a project at all stages of its life cycle	Project "Drone Systems Engineering. Part 1"; *Applied Mechanics and Engineering***; *Systems Engineering***; Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research; Aerospace Systems;	
UK-1	Able to critically analyze problem situations based on	*Machine Learning and Big Data Mining***;	

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
	a systematic approach and develop an action strategy	*From Data Acquisition to Data Treatment***; Cross-Cultural Training; Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research; Programming; Databases; Advanced Methods of Remote Sensing and Geoinformation Systems; Structures & Materials Modeling; Project "Drone Systems Engineering. Part 1";	
OPK-2	Able to improve and implement new mathematical methods for solving applied problems	*Programming;* *Aerospace Systems;* *Structures & Materials Modeling;*	
OPK-3	Able to develop mathematical models and analyze them when solving problems in the field of professional activity	*Programming;* *Aerospace Systems;* *Structures & Materials Modeling;* *Project "Drone Systems Engineering. Part 1";*	
PC-1	Able to formulate goals and objectives of scientific research in the field of applied mathematics and computer science, computer technology and modern programming technologies, select methods and means for solving problems	*Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research;* *Programming;* *Databases;* *Advanced Methods of Remote Sensing and Geoinformation Systems;* *Machine Learning and Big Data Mining**;* *From Data Acquisition to Data Treatment**;* *Applied Mechanics and Engineering**;* *Systems Engineering**;* *Virtual Reality and Computer Vision**;* *Modeling and Validation**;*	
PK-3	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and spacecraft flight control	*Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research;* *Aerospace Systems;* *Structures & Materials Modeling;* *Project "Drone Systems Engineering. Part 1";* *Applied Mechanics and Engineering**;* *Systems Engineering**;*	

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
PK-5	Able to analyze, including in English, methods for studying ballistic and dynamic characteristics when modeling spacecraft flight trajectories	*Practical Training in Receiving Remote Sensing Data from Satellites and its Interpretation (online from RUDN Mission Control Center) / Research;* *English Language;* *Aerospace Systems;* *Structures & Materials Modeling;* *Applied Mechanics and Engineering**;* *Systems Engineering**;* *Russian as a Foreign Language;* *Advanced Methods of Remote Sensing and Geoinformation Systems;*	

* - to be filled out in accordance with the competency matrix and SUP EP VO

** - elective disciplines/practices

4. SCOPE OF DISCIPLINE AND TYPES OF STUDY WORK

The total complexity of the discipline “Dynamics and Control of Space Systems” is “10” credit units.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time study.

Type of educational work	**TOTAL,**ac.ch.		**Semester(s)**	
			3	**4**
Contact work, ac.ch.	*190*		*126*	*64*
Lectures (LK)	80		54	26
Laboratory work (LR)	thirty		18	12
Practical/seminar sessions (SZ)	80		54	26
Independent work of students, ac.ch.	*143*		*54*	*89*
Control (exam/test with assessment), academic degree.	*27*		*0*	*27*
Total labor intensity of the discipline	**ac.ch.**	***360***	*180*	*180*
	credit units	***10***	*5*	*5*

5. CONTENT OF DISCIPLINE

Table 5.1. Contents of the discipline (module) by type of academic work

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
Section 1	Methods for optimizing the orbital structures of satellite systems	1.1	General principles for satellite systems design. Methods for constructing systems for global continuous observation of the Earth's regions. Ballistic design of systems for continuous zonal monitoring of the Earth's surface.	LC, LR, SZ
		1.2	Determination of the time gap in the monitoring of one frontal group of the entire surface of the Earth. Methods for constructing satellite systems for periodical observation of the Earth's surface. Construction of ballistic structures for monitoring systems of the entire surface of the Earth with small gaps in observation. Construction of systems for periodical monitoring of an area on the Earth's surface. Ballistic design of spacecraft probabilistic systems.	LC, LR, SZ
		1.3	Spacecraft communication systems. Satellite radio navigation systems. Features of the construction of meteorological satellite systems. Construction of outer space monitoring systems. Ballistic design of systems using ballistically coupled spacecraft groups.	LC, LR, SZ
		1.4	Space tether systems. Orbital functioning of the connected space objects. Rapprochement in space using tether systems. The method of forming optimal modes of tether systems controlled movement in solving practical problems.	LC, LR, SZ
Section 2	Numerical and analytical methods for optimizing orbital maneuvers	2.1	Equations of spacecraft motion in deviations from motion along the circular reference orbit. Single-impulse maneuvers. Changes in the shape of the orbit as a result of the application of velocity impulse. Estimation of the magnitude of the maneuvers, the choice of the initial deviation along the orbit at the spacecraft start. Necessary optimality conditions. The main types of tasks for spacecraft optimal maneuvering.	LC, LR, SZ
		2.2	Optimal maneuvering in the space debris problem. Spacecraft avoidance maneuvers from collision with space debris. Assessment of maneuvers performed by an active space object.	LC, LR, SZ
		2.3	Optimal maneuvering in the space service problem. Planning the optimal service for a constellation of spacecraft in non-coplanar orbits. Assessment of maneuvers performed by active spacecraft when transferring to the vicinity of serviced objects.	LC, LR, SZ
Section 3	Methods for calculating the disturbed motion of spacecraft in the force field of several celestial bodies	3.1	The two-body problem. Kepler's empirical laws. First integrals for the Kepler problem. Phase portrait. Osculating elements. Equations of indignant motion in the occupying elements.	LC, LR, SZ
		3.2	The three-body problem. The circular restricted three-body problem. Stability of libration points. The Hill's problem. The Sitnikov problem. The gravitational potential of the Earth. The Euler problem of two fixed attracting centers. Generalized problem of two fixed centers.	LC, LR, SZ

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
		3.3	The N-body problem. The stability of the solar system. Laplace's theorem. KAM theory. Jacques Lascard's research.	LC, LR, SZ
		3.4	The motion of a rigid body in a central gravitational field. Satellite approximation. Limited formulation for the satellite motion problem. Relative equilibria. The problem of Leonov and the stub.	LC, LR, SZ
		3.5	Influence of light pressure on the motion of a spacecraft. Solar sail.	LC, LR, SZ

* - to be filled out only for full-time education: LC – lectures; LR – laboratory work; SZ – practical/seminar classes.

6. MATERIAL AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support of the discipline

Audience type	Auditorium equipment	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	An auditorium for conducting lecture-type classes, equipped with a set of specialized furniture; board (screen) and technical means of multimedia presentations.	
Computer class	A computer class for conducting classes, group and individual consultations, ongoing monitoring and intermediate certification, equipped with personal computers ([Parameter] pcs.), a whiteboard (screen) and technical means for multimedia presentations.	
Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, ongoing monitoring and intermediate certification, equipped with a set of specialized furniture and technical means for multimedia presentations.	
For independent work	An auditorium for independent work by students (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to EIOS.	

* - the audience for independent work of students is MANDATORY!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF DISCIPLINE

Main literature:

1. Averkiev NF, Vlasov SA, Bogachev SA, Zhatkin AT, Kulvits AV Fundamental principles of ballistic design of launch vehicles and satellite systems: textbook. -- SPb.: VKA named after AF Mozhaisky, 2017. -- 300 p.

2. Baranov AA Spacecraft manoeuvres in the vicinity of a circular orbit. -- M.: Publishing house "Sputnik +", 2016. -- 512 p.

3. Bordovitsyna TV, Avdyushev VA The motion of artificial earth satellites theory. Analytical and numerical methods: a tutorial. -- Tomsk: Publishing house of Tomsk State University, 2007. -- 178 p.

4. Beletsky VV Essays on the motion of celestial bodies. Issue No. 4. -- M.: Publishing group URSS, 2017. -- 432 p.

Additional literature:

1. Vlasov SA, Kulvits AV, Skripnikov AN Spacecraft flight theory: textbook. -- SPb: VKA named after AF Mozhaisky, 2018. -- 412 p.

2. Ivanov NM, Lysenko LN Ballistics and navigation of spacecraft: textbook. 3rd Edition. -- M.: Drofa, 2016. -- 528 p.

3. Sazonov VV, Barbashova TF Lectures on space flight mechanics. Special course. -- M.: Publishing house of Moscow State University, 2018. -- 152 p.

4. Mechanical engineering. Encyclopedia. Editorial council: KV Frolov and others. -- M.: Mechanical engineering. Rocket and space technology. Vol. IV-22 / AP Ajyan, EL Akim, OM Alifanov and others; executive editor: VP Legostaev, editors: EA Akim, OM Alifanov, VV Vakhnichenko, GN Zaslavsky, AA Dyadkin, VV Ivashkin, BI Katorgin, Yu.N. Razumny, Yu.P. Ulybyshev, Book 1. 2012. Section 2.5. Satellite systems. P. 180-224.

5. Razumny Yu.N., Shkolnikov DO Basic integrals of unperturbed motion and Kepler's equation: a tutorial. -- M.: Publishing house of MSTU im. NE Bauman, 2011. -- 38 p.

Resources of the information and telecommunications network "Internet":

1. EBS of RUDN University and third-party EBS, to which university students have access based on concluded agreements

- Electronic library system of 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 "Trinity Bridge"

2. Databases and search engines

- electronic fund of legal and regulatory 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/

Educational and methodological materials for students' independent work when mastering a discipline/module:*

1. A course of lectures on the discipline "Dynamics and control of space systems."

* - all educational and methodological materials for students' independent work are posted in accordance with the current procedure on the discipline page in TUIS!

8. ASSESSMENT MATERIALS AND POINT-RATING SYSTEM FOR ASSESSING THE LEVEL OF COMPETENCIES FOR A DISCIPLINE

Evaluation materials and point-rating system* for assessing the level of development of competencies (parts of competencies) based on the results of mastering the discipline"Dynamics

and control of space systems" are presented in the Appendix to this Work Program of the discipline.

* - OM and BRS are formed on the basis of the requirements of the relevant local regulatory act of RUDN University.

DEVELOPERS:

Professor		Baranov Andrey Anatolevich
Position, PBU	*Signature*	*Last name I.O.*
Assistant professor		Karatunov Maxim Olegovich
Position, PBU	*Signature*	*Last name I.O*

HEAD OF BUP:

Head of the department		Razumny Yuri Nikolaevich
Position PBU	*Signature*	*Last name I.O.*

HEAD OF OP VO:

Professor		Razumny Yuri Nikolaevich
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