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

Academy of Engineering

(name of the main educational unit (MEU) that developed the educational program of higher education)

WORKING PROGRAM OF THE DISCIPLINE

ADVANCED METHODS OF SPACE FLIGHT MECHANICS

(name of discipline/module)

Recommended for the field of study/specialty:

27.04.04 CONTROL IN TECHNICAL SYSTEMS

(code and name of the field of study/specialty)

The discipline is mastered within the framework of the implementation of the main professional educational program of higher education (EP HE):

Artificial Intelligence, Machine Learning, and Space Science

(name (profile/specialization) of the educational institution of higher education)

2026

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Advanced Methods of Space Flight Mechanics" is part of the Master's program "Artificial Intelligence, Machine Learning, and Space Sciences" (27.04.04 "Control in Technical Systems") and is studied in the third semester of the second year. The course is offered by the Department of Mechanics and Control Processes. It consists of two sections and five topics and focuses on methods for solving design problems related to the formation and calculation of the motion of spacecraft and orbital structures for various purposes, solving specific engineering problems related to launch and maneuvering in orbit, and applying mathematical modeling methods to solve these problems using modern computer tools.

The purpose of mastering the discipline is to acquire knowledge, skills, abilities and experience in the field of designing space satellite systems for various purposes, maneuvering spacecraft in orbit, methods of their calculation and optimization, characterizing the stages of the formation of competencies and ensuring the achievement of the planned results of mastering the educational program.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the course "Modern Methods of Space Flight Mechanics" aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies developed in students while mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
GPC-10	Capable of managing the development of methodological and regulatory documents, technical documentation in the field of automation of technological processes and production, including on the life cycle of products and their quality	GPC-10.1 Familiar with the basic approaches to the development of methodological and regulatory documents, technical documentation in the field of automation of technological processes and production; GPC-10.2 Has a command of approaches to managing the development of technical documentation and regulatory documents in the field of automation of technological processes and production, including the life cycle of products and their quality;
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology	GPC-3.1 Knows the basic approaches to solving control problems in technical systems; GPC-3.2 Able to apply basic approaches based on the latest achievements of science and technology to solving control problems in technical systems; GPC-3.3 Proficient in methods of solving control problems in technical systems based on the latest achievements of science and technology;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	PC-2.1 Knows modern theoretical and experimental methods used to develop mathematical models of studied objects and processes of professional activity; PC-2.2 Able to determine the effectiveness of the methods used to develop mathematical models of the objects and processes under study; PC-2.3 Has a command of modern theoretical and experimental methods for developing mathematical models of objects and processes of professional activity in the field of study;

3. PLACE OF THE DISCIPLINE IN THE STRUCTURE OF THE EDUCATIONAL EDUCATIONAL INSTITUTION

Course "Modern Methods of Space Flight Mechanics" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Modern Methods of Space Flight Mechanics".

Table 3.1. List of components of the educational program of higher education that contribute to the achievement of the planned results of mastering the discipline

Cipher	**Name of competence**	**Previous courses/modules, practical training***	**Subsequent disciplines/modules, practices***
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology	Research work / Scientific research work (acquiring primary skills in scientific research work); Applied Statistics; Design and Analysis of Algorithms;	Undergraduate practice / Pre-graduation practice;
GPC-10	Capable of managing the development of methodological and regulatory documents, technical documentation in the field of automation of technological processes and production, including on the life cycle of products and their quality	Research work / Scientific research work (acquiring primary skills in scientific research work);	Undergraduate practice / Pre-graduation practice;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	Research work / Scientific research work (acquiring primary skills in scientific research work); Mathematics for Spatial Sciences; Operations Research and Optimization Techniques;	Undergraduate practice / Pre-graduation practice;

* - filled in accordance with the competency matrix and the SUP EP HE

** - elective courses/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF EDUCATIONAL WORK

The total workload of the course “Modern Methods of Space Flight Mechanics” is 3 credit units.

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

Type of academic work	**TOTAL,**academic hours		**Semester(s)**
			3
Contact work, academic hours	*34*		*34*
Lectures (LC)	17		17
Laboratory work (LW)	0		0
Practical/seminar classes (SC)	17		17
Independent work of students, academic hours	*74*		*74*
Control (exam/test with assessment), academic hours	*0*		*0*
Total complexity of the discipline	**academic hours**	***108***	*108*
	credit	***3***	*3*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of academic work

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 1	Methods for calculating the disturbed motion of spacecraft in the force field of several celestial bodies	1.1	The two-body problem. Kepler's empirical laws. First integrals of the Kepler problem. Phase portrait. Osculating elements. Equations of perturbed motion in occupied elements.	The two-body problem: formulation, equations of motion, reduction to the one-body problem. Kepler's empirical laws: the law of ellipses, areas, and harmony. First integrals of Kepler's problem: energy integral, area integral, Laplace integral. Phase portrait: orbital types (ellipse, parabola, hyperbola). Osculating elements: semi-major axis, eccentricity, inclination, longitude of the ascending node, argument of periapsis, mean anomaly. Equations of perturbed motion in osculating elements.	LC, SC
		1.2	The three-body problem. Restricted circular three-body problem. Stability of libration points. Hill regions. Sitnikov's problem. Earth's gravitational potential. Euler's problem of two fixed centers of attraction. Generalized problem of two fixed centers of attraction.	The three-body problem: general formulation, difficulties of solution. The restricted circular three-body problem: equations of motion in the synodic coordinate system. Libration points: collinear and triangular, their stability. Hill regions (zero velocities). The Sitnikov problem (binary system). The gravitational potential of the Earth: spherical and nonspherical potential, zonal, tesseral, and sectoral harmonics. Euler's problem on two fixed centers. The generalized problem of two fixed centers.	LC, SC
		1.3	The N-body problem. Stability of the solar system. Laplace's theorem. KAM theory. Research of Jacques Lascar.	The N-body problem: formulation and solution difficulties. Stability of the Solar System: historical overview, modern methods. Laplace's theorem. KAM theory (Kolmogorov-Arnold-Moser): integrable and almost integrable systems, invariant tori. Jacques Lascar's research on the long-term stability of the Solar System.	LC, SC
Section 2	Motion of a rigid body in a central gravitational field	2.1	Satellite approximation. A limited formulation of the satellite motion problem. Relative equilibria. The Leonov-and-the-plug problem.	Satellite approximation: assumptions about the satellite's size and gravitational field. A limited formulation of the problem of satellite motion in a central field, taking into account the gravitational moment. Relative equilibria: stable and unstable equilibrium positions of a satellite in orbit. The Leonov-and-the-Stub problem: stability of satellite rotation.	LC, SC
		2.2	The influence of light pressure on spacecraft motion. Solar sail.	Solar radiation pressure: nature and model of its impact on spacecraft. Effect of radiation pressure on orbit: shape and orientation perturbations. Solar sail: operating principle and design. Spacecraft motion control using solar sails. Navigation and orbital correction tasks.	LC, SC

* - to be completed only for FULL-TIME education: LC – lectures; LW – laboratory work; SC – practical/seminar classes.

6. LOGISTIC AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support for the discipline

Audience type	Equipment of the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	A lecture hall equipped with specialized furniture, a whiteboard (screen), and multimedia presentation equipment.	
Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with a set of specialized furniture and technical means for multimedia presentations.	
For independent work	A classroom for independent student work (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the classroom for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. Averkiev N.F., Vlasov S.A., Bogachev S.A., Zhatkin A.T., Kulvits A.V. Ballistic principles of designing launch vehicles and satellite systems: textbook. – St. Petersburg: A.F. Mozhaisky Aerospace Forces, 2017. – 300 p.

2. Baranov A.A. Maneuvering of spacecraft in the vicinity of a circular orbit. – M.: Publishing House “Sputnik+”, 2016. – 512 p.

3. Bordovitsyna T.V., Avdyushev V.A. Theory of motion of artificial Earth satellites. Analytical and numerical methods: a tutorial. – Tomsk: Publishing house of Tomsk. University, 2007. – 178 p.

4. Beletsky V.V. Essays on the motion of cosmic bodies. Issue No. 4. – M.: URSS Publishing Group, 2017. – 432 p.

Further reading:

1. Vlasov S.A., Kulvits A.V., Skripnikov A.N. Spacecraft Flight Theory: Textbook. – St. Petersburg: A.F. Mozhasky Space Academy, 2018. – 412 p.

2. Ivanov N.M., Lysenko L.N. Ballistics and navigation of spacecraft: textbook. 3rd edition. – M.: Drofa, 2016. – 528 p.

3. Sazonov V.V., Barbashova T.F. Lectures on space flight mechanics. Special course. – M.: Moscow State University Publishing House, 2018. – 152 p.

4. Mechanical Engineering. Encyclopedia. Editorial Board: K. V. Frolov (chairman) et al. - Moscow: Mechanical Engineering. Rocket and Space Technology. Vol. IV-22 / A. P. Adzhyan, E. L. Akim, O. M. Alifanov et al.; ed. V. P. Legostaev, editors E. A. Akim, Yu. P. O. M. Alifanov, V. V. Vakhnichenko, G. N. Zaslavsky, A. A. Dyadkin, V. V. Ivashkin, B. I. Katorgin, Yu. N. Razumny, Yu. P. Ulybyshev, Book 1. 2012. Section 2.5. Satellite Systems. P. 180-224.

5. Razumny Yu.N., Shkolnikov D.O. Basic integrals of unperturbed motion and the Kepler equation: a tutorial. – Moscow: Publishing house of Bauman Moscow State Technical University, 2011. – 38 p.

Resources of the information and telecommunications network "Internet":

1. RUDN University Electronic Library System and third-party electronic library systems to which university students have access based on concluded agreements

- RUDN University Electronic Library System – RUDN University Electronic Library System https://mega.rudn.ru/MegaPro/Web
- Electronic Library System "University Library Online" http://www.biblioclub.ru
- EBS Yurayt http://www.biblio-online.ru
- Electronic Library System "Student Consultant" www.studentlibrary.ru
- EBS “Knowledge” https://znanium.ru/

2. Databases and search engines

- Sage https://journals.sagepub.com/
- Springer Nature Link https://link.springer.com/
- Wiley Journal Database https://onlinelibrary.wiley.com/
- Scientometric database Lens.org https://www.lens.org

Educational and methodological materials for independent work of students in mastering a discipline/module:*

1. Lecture course on the subject "Modern methods of space flight mechanics".

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

DEVELOPER:

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