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

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

COURSE SYLLABUS

SPACE FLIGHT MECHANICS
(name of discipline/module)

Recommended by the Didactic Council for the Education Field of:

27.03.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the area of training/specialty)

The course instruction is implemented within the professional education programme of higher education:

DATA ENGINEERING AND SPACE SYSTEMS CONTROL
(name (profile/specialization) EP HE)

2024

1. GOAL OF DISCIPLINE MASTERING

The discipline “Space Flight Mechanics” is included in the bachelor’s program “Data Engineering and Space Systems Control” in the direction of 27.03.04 “Control in Technical Systems” and is studied in the 3rd, 4th, 5th, 6th, 7th semesters of the 2nd, 3rd, 4th courses. The discipline is implemented by the Department of Mechanics and Control Processes. The discipline consists of 12 sections and 56 topics and is aimed at studying the theoretical foundations of the mechanics of space flight, forecasting the movement of spacecraft, the theory of maneuvering, trajectory measurements and interplanetary flights. Particular attention is paid to the analysis of methods for solving typical problems and analysis of the scope of their application in professional activities.

The purpose of mastering the discipline is to develop fundamental knowledge and skills in applying methods of space flight mechanics to solve astronautics problems, necessary for professional activities and mastering subsequent disciplines.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline “Space Flight Mechanics” 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)
GPC -1	Able to analyze professional tasks based on regulations, laws and methods in the field of natural sciences and mathematics	GPC-1.1 Has basic knowledge acquired in the field of mathematical and (or) natural sciences; GPC -1.2 Able to use them in professional activities; GPC-1.3 Has the skills to select methods for solving problems of professional activity based on theoretical knowledge;
GPC -11	Able to understand the operating principles of modern information technologies and use them to solve professional problems	GPC-11.1 Knows digital methods and technologies used in professional activities; GPC -11.2 Able to apply digital methods and technologies in professional activities to study and model objects of professional activities, data analysis, and presentation of information; GPC-11.3 Confident in digital methods and technologies in professional activities (in the field of management in technical systems) for: studying and modeling objects of professional activity, data analysis, presentation of information;
GPC -2	Able to formulate tasks of professional activity based on knowledge, specialized sections of mathematical and natural science disciplines (modules)	GPC -2.1 Proficient in mathematical methods, programming fundamentals and specialized programming systems for implementing algorithms for solving applied problems; GPC -2.2 Able to select and adapt mathematical methods and software to solve practical problems; GPC -2.3 Has the skills to develop and implement algorithms for solving applied problems in the field of professional activity;
GPC -3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	GPC-3.1 Knows the theoretical foundations and principles of mathematical modeling; GPC -3.2 Able to develop and use methods of mathematical modeling, information technologies to solve problems of applied mathematics; GPC-3.3 Possesses practical skills in solving problems of applied mathematics, methods of mathematical modeling, information technologies and the basics of their use in professional activities, professional thinking skills and an arsenal of methods and approaches necessary for the adequate use of methods of modern mathematics in theoretical and applied problems;

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
GPC -6	Able to develop and use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical application in the field of his professional activity	GPC-6.1 Knows basic algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical use in the field of their professional activities; GPC -6.2 Can use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical use in the field of their professional activities; GPC-6.3 Confidently masters algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical application in the field of his professional activity;
PC-1	Capable of collecting, processing and interpreting modern scientific research data necessary to draw conclusions on relevant scientific research, including Earth remote sensing data	PC-1.1 Knows modern methods of how to collect, process and interpret modern scientific research data necessary to form conclusions on relevant scientific research; PC-1.2 Able to apply modern methods and tools for processing and interpreting scientific research data; PC-1.3 Possesses the basic skills of collecting, processing and interpreting modern scientific research data necessary to form conclusions on relevant scientific research;
PC-2	Able to participate in the development of circuit documentation for the flight control system of launch vehicles and spacecraft, in the preparation of publications based on the results of research and development	PC-2.1 Knows the basic approaches to the development of mathematical models of components, functional modules and instruments of the flight control system of launch vehicles and spacecraft; PC-2.2 Able to compile analytical reviews and scientific and technical reports on the results of research and development; PC-2.3 Has the skills to design functional units and blocks of the flight control system for launch vehicles and spacecraft;
PC-4	Able to formulate, analyze and solve engineering problems in the field of ballistics, propulsion mechanics and spacecraft motion control based on professional knowledge	PC-4.1 Knows the basic concepts and basic algorithms for solving problems in the field of ballistics, motion mechanics and motion control based on automated and automatic systems; PC-4.2 Able to solve engineering problems of an analytical nature in the field of ballistics, motion mechanics and motion control of spacecraft based on professional knowledge; PC-4.3 Possesses the skills of using mathematical methods for processing information obtained as a result of experimental research, basic methods of analyzing the mechanics of motion and controlling the motion of spacecraft based on standard methods and software packages;

3. PLACE OF DISCIPLINE IN THE STRUCTURE OF HE EP

Discipline "Space Flight Mechanics" 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 “Space Flight Mechanics”.

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*
GPC -1	Able to analyze professional tasks based on regulations, laws and methods in the	Mathematical analysis; Algebra and Geometry; Physics;	Technological Training; Undergraduate practice / Pre-graduate practice;

Cipher	Name of competency	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
	field of natural sciences and mathematics		
GPC -2	Able to formulate tasks of professional activity based on knowledge, specialized sections of mathematical and natural science disciplines (modules)	Mathematical analysis; Algebra and Geometry;	Technological Training; Undergraduate practice / Pre-graduate practice;
GPC -3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	Mathematical analysis; Algebra and Geometry;	Technological Training; Undergraduate practice / Pre-graduate practice;
GPC -6	Able to develop and use algorithms and programs, modern information technologies, methods and means of control, diagnostics and management, suitable for practical application in the field of his professional activity	Computer Science and Programming;	Undergraduate practice / Pre-graduate practice;
GPC -11	Able to understand the operating principles of modern information technologies and use them to solve professional problems		Undergraduate practice / Pre-graduate practice; Technological Training;
PC-1	Capable of collecting, processing and interpreting modern scientific research data necessary to draw conclusions on relevant scientific research, including Earth remote sensing data	Computer Science and Programming;	Technological Training; Undergraduate practice / Pre-graduate practice;
PC-2	Able to participate in the development of circuit documentation for the flight control system of launch vehicles and spacecraft, in the preparation of publications based on the results of research and development		Undergraduate practice / Pre-graduate practice;
PC-4	Able to formulate, analyze and solve engineering problems in the field of ballistics, propulsion mechanics and spacecraft motion control based on professional knowledge		Technological Training; Undergraduate practice / Pre-graduate practice;

* - 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 labor intensity of the “Space Flight Mechanics” discipline is “25” credits.

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**	**5**	**6**	**7**
Contact work, ac.ch.	*429*		*54*	*51*	*108*	*108*	*108*
Lectures (LC)	160		18	34	36	36	36
Laboratory work (LR)	143		18	17	36	36	36
Practical/seminar sessions (SZ)	126		18	0	36	36	36
Independent work of students, ac.ch.	*381*		*18*	*93*	*108*	*45*	*117*
Control (exam/test with assessment), academic degree.	*90*		*0*	*0*	*36*	*27*	*27*
Total labor intensity of the discipline	**ac.ch.**	***900***	*72*	*144*	*252*	*180*	*252*
	credit units	***25***	*2*	*4*	*7*	*5*	*7*

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	Introduction	1.1	Mechanics of space flight in the structure of scientific and technical knowledge. Structure of the discipline. Areas of application of space flight mechanics methods	OK
		1.2	Dynamics of bodies of variable mass. The law of universal gravitation. Basic laws of mechanics.	LC, NW
		1.3	Spherical trigonometry	LC, NW
Section 2	Unperturbed motion of the spacecraft	2.1	Basic concepts and definitions. Equations of motion in a gravitational field	OK
		2.2	Integrals of the equations of unperturbed motion	LC, NW
		2.3	Trajectory equation. Types of orbits. Geometric characteristics of orbits	LC, NW
		2.4	Kinematic motion parameters	OK
		2.5	Kepler's equation	LC, LR, SZ
		2.6	Determination of Keplerian orbital elements from the initial conditions of motion	LR, NW
		2.7	Determination of kinematic parameters of motion using Keplerian orbital elements	LR, NW
		2.8	Spacecraft flight path	LC, LR, SZ
		2.9	Determination of Keplerian orbital elements from two positions of the spacecraft	LC, LR, SZ
Section 3	Disturbed motion of the spacecraft center of mass	3.1	General characteristics of disturbances and basic methods for studying disturbed motion	OK
		3.2	Osculating element method	OK
		3.3	Analysis of perturbed motion in near-circular orbits	LC, LR, SZ
		3.4	The influence of the non-centrality of the Earth's gravitational field	LR, NW
		3.5	Influence of the Earth's atmosphere	LR, NW
		3.6	The influence of the attraction of celestial bodies	LR, NW
		3.7	Effect of light pressure	LR, NW
Section 4	Dynamics of spacecraft motion relative to the center of mass	4.1	Moments of forces acting on a spacecraft	OK
		4.2	Differential equations of rotational motion of a spacecraft	OK
		4.3	Kinematic Poisson relations. Energy integral	LC, NW
		4.4	Energy integral. Relative equilibrium of the spacecraft. Equilibrium stability	LC, LR, SZ
		4.5	Limits of fluctuations. Conditions for non-turnover	LC, LR, SZ
		4.6	Methods for orienting and stabilizing a spacecraft	LC, LR, SZ
Section 5	Orbital maneuvers in the central gravitational field	5.1	Basic principles of the theory of maneuvers	OK
		5.2	Transition maneuvers	LC, LR, SZ
		5.3	Meeting in coplanar orbits	LC, LR, SZ
		5.4	Meeting on non-coplanar orbits	LC, LR, SZ
		5.5	Numerical methods for optimizing and increasing the accuracy of maneuver parameters	LC, LR, SZ
		5.6	Maneuvering with an engine having limited constant thrust	LC, LR, SZ

Section number	Name of the discipline section	Contents of the section (topic)		Type of educational work*
Section 6	Coordinate systems	6.1	Celestial coordinate system. Heliocentric coordinate system	LC, NW
		6.2	Geocentric coordinate systems. Connected coordinate systems	LC, NW
		6.3	Transition between coordinate systems	LK, LR
Section 7	Time scales	7.1	Solar, sidereal and atomic time	OK
		7.2	Dynamic and coordinated time	OK
		7.3	Transition between time scales	LC, LR, SZ
Section 8	Methods for predicting the motion of a spacecraft	8.1	Forms of representation of the Earth's gravitational field	LC, LR, SZ
		8.2	Mathematical modeling of disturbing forces	LC, LR, SZ
		8.3	Analytical methods for motion forecasting	LC, LR, SZ
		8.4	Representation of the right-hand sides of the equations of motion as functions of orbital elements	LC, NW
		8.5	Numerical methods for motion prediction	LC, LR, SZ
		8.6	Methods of the theory of special perturbations in spacecraft dynamics problems	LC, NW
Section 9	Determination of spacecraft motion parameters based on trajectory measurements	9.1	Characteristics and classification of measurements. Conversion of measurement information.	LK, LR
		9.2	Lambert problem	LC, NW
		9.3	Least square method	LC, LR, SZ
		9.4	Kalman filters	LC, LR, SZ
Section 10	Dynamics of launching a spacecraft into low-Earth orbit	10.1	Starting coordinate systems. Determining the optimal start time	LC, NW
		10.2	Rocket engines. Forces and moments acting on the launch vehicle	LC, NW
		10.3	Mathematical modeling of launch vehicle motion	LC, LR, SZ
Section 11	Dynamics of spacecraft descent to Earth	11.1	General scheme of descent. Requirements for the descent trajectory	OK
		11.2	Mathematical modeling of the movement of the descent vehicle in the atmosphere	LC, LR, SZ
Section 12	Interplanetary flights	12.1	Methods for calculating sections of interplanetary trajectories	OK
		12.2	Flight diagrams of interplanetary vehicles. Start windows.	OK
		12.3	Mathematical modeling of the movement of interplanetary vehicles	LC, LR, SZ
		12.4	Optimization of interplanetary trajectories	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. Vlasov S.A., Kulvits A.V., Skripnikov A.N. Theory of spacecraft flight: textbook. – St. Petersburg: VKA named after A.F. Mozhasky, 2018 – 412 p.

2. Averkiev N.F., Vlasov S.A., Bogachev S.A., Zhatkin A.T., Kulvits A.V. Ballistic fundamentals of designing launch vehicles and satellite systems: textbook. – St. Petersburg: VKA named after A.F. Mozhaisky, 2017. – 300 p.

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

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

5. N.M. Ivanov, L.N. Lysenko. Ballistics and navigation of spacecraft. - M.: Publishing house of MSTU im.N. E. Bauman, 2016 - 524 p.

Additional literature:

1. DA Vallado. Fundamentals of Astrodynamics and Applications. 4th ed. - USA, Hawthorne: Microcosm Press, 2013 - 1135 p. ISBN 13: 9781881883180. ISBN 10: 1881883183

2. O. Montenbruck, E. Gill. Satellite Orbits: Models, Methods and Applications. - Germany, Berlin: Springer, 2000 - 371 p. ISBN 978-3-540-67280-7

3. Ts.V. Soloviev, E.V. Tarasov. Forecasting interplanetary flights. - M: “Mechanical Engineering”, 1973 - 401 p.

4. M.B. Balk, V.G. Demin, A.L. Kunitsyn. Collection of problems on celestial mechanics and cosmodynamics.M: “Science”, 1972 - 336 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 University - EBS RUDN Universityhttp://lib.rudn.ru/MegaPro/Web
- EBS “University Library Online”http://www.biblioclub.ru
- EBS Lawhttp://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 documentationhttp://docs.cntd.ru/
- Yandex search enginehttps://www.yandex.ru/
- search systemGoogle https://www.google.ru/
- abstract databaseSCOPUS 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 “Space Flight Mechanics”.

* - 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“Space Flight Mechanics” 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.

DEVELOPER:

Professor		Razumny Yuri Nikolaevich
Position	*Signature*	*Last name I.O.*

HEAD OF BUP:

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

HEAD OF OP VO:

Professor		Razumny Yuri Nikolaevich
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