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**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

EQUATIONS OF MATHEMATICAL PHYSICS

(name of discipline/module)

Recommended for the field of study/specialty:

27.03.04 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):

DATA SCIENCE AND SPACE SYSTEMS

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

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Equations of Mathematical Physics" is part of the bachelor's program "Data Science and Space Systems" in the 27.03.04 "Control in Technical Systems" program and is studied in the 7th semester of the 4th year. The course is offered by the Department of Mechanics and Control Processes. It consists of two sections and 17 topics and focuses on the fundamentals of differential equation theory, the main methods of analytical, approximate-analytical, and numerical integration of differential equations and systems of differential equations, the main methods of stability analysis, and examples of the application of theory and methods for solving differential equations in various applied problems.

The purpose of mastering the discipline is to study the theory of differential equations and master the methods of their solution, increasing the general level of mathematical culture of students.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline "Equations of Mathematical Physics" 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-2	Able to formulate objectives for professional activity based on knowledge of specialized sections of mathematical and natural science disciplines (modules)	GPC-2.1 Has a command of 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 Possesses skills in developing and implementing 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, skills of professional thinking and an arsenal of methods and approaches necessary for the adequate use of methods of modern mathematics in theoretical and applied problems;

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

Course "Equations of Mathematical Physics" 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 "Equations of Mathematical Physics".

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-2	Able to formulate objectives for professional activity based on knowledge of specialized sections of mathematical and natural science disciplines (modules)	Research work / Scientific research work; Technological Training; Mathematical analysis; Space Flight Mechanics; Numerical Methods; Automatic Control Theory; Algebra and Geometry; Analysis of Geoinformation Data;	Technological Training; Undergraduate Training;
GPC-3	Able to use fundamental knowledge to solve basic control problems in technical systems in order to improve in professional activities	Mathematical analysis; Space Flight Mechanics; Theoretical Mechanics; Numerical Methods; Automatic Control Theory; Algebra and Geometry; Theory of Probability and Mathematical Statistics; Differential equations; Complex analysis; Optimal Control Methods; Analysis of Geoinformation Data; Research work / Scientific research work; Technological Training;	Technological Training; Undergraduate Training;

* - 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 “Equations of Mathematical Physics” is 8 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)
			7
<i>Contact work, academic hours</i>	108		108
Lectures (LC)	54		54
Laboratory work (LW)	0		0
Practical/seminar classes (SC)	54		54
<i>Independent work of students, academic hours</i>	153		153
<i>Control (exam/test with assessment), academic hours</i>	27		27
Total complexity of the discipline	academic hours	288	288
	credit	8	8

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	Equations of mathematical physics	1.1	Basic equations of mathematical physics	Equations of mathematical physics as partial differential equations describing physical processes. Classification of equations: hyperbolic for wave processes, parabolic for heat conduction and diffusion processes, elliptic for stationary processes. Examples: wave equation, heat equation, Laplace and Poisson equations. Boundary and initial conditions as necessary additions to obtain a unique solution.	LC, SC
		1.2	Cauchy problem for the equation of string vibrations	The Cauchy problem as a formulation of a problem with initial conditions for an infinite string. The equation of string vibrations as a one-dimensional wave equation. Initial conditions: the initial shape of the string and the initial velocity distribution of its points. Physical interpretation: description of the propagation of small transverse vibrations of an infinite string.	LC, SC
		1.3	d'Alembert's formula	D'Alembert's formula as an analytical solution to the Cauchy problem for the wave equation on an infinite line. Expression of the solution in terms of initial conditions: half the sum of the initial deviations propagated to the right and left, plus the integral of the initial velocities. Waves traveling to the right and left serve as the fundamental structure of the solution. Characteristics of the wave equation as lines along which disturbances propagate with finite velocity.	LC, SC
		1.4	Vibrations of a semi-bounded string	A semi-bounded string with one fixed or free endpoint on the boundary. The extension method for reducing a problem on a half-line to a problem on the entire line. Even extension of the initial conditions to the free endpoint. Odd extension of the initial conditions to the fixed endpoint. Reflection of a wave from the boundary with or without sign change.	LC, SC
		1.5	Fourier series	Fourier series as decompositions of periodic functions into sums of trigonometric functions. Trigonometric system of functions: sines and cosines of multiple arcs. Fourier coefficients as integrals of the product of a function by the corresponding trigonometric functions. Convergence of Fourier series for piecewise smooth functions. Sine expansions for odd functions and cosine expansions for even	LC, SC

Section number	Name of the discipline section	Topic Title	Topic Contents	Type of academic work*
			functions.	
		1.6	Solution of the Cauchy problem for the equation of vibrations of a string with fixed ends	LC, SC
		1.7	Forced vibrations of a string	LC, SC
		1.8	Equation of heat propagation in a rod	LC, SC
		1.9	Thermal conductivity in the final rod	LC, SC
		1.10	Laplace's equation	LC, SC

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				maximum principle for harmonic functions.	
		1.11	Writing in polar coordinates	Laplace's equation in polar coordinates on a plane. Expression of the Laplace operator in terms of derivatives with respect to radius and angle. Separation of variables in polar coordinates with representation of the solution as a product of radial and angular functions. Equations for the radial and angular parts. Solutions to the angular part as sines and cosines of an integer number of angles. Solutions to the radial part as power functions and logarithms.	LC, SC
		1.12	Fourier method for the Laplace equation	The Fourier method of separation of variables for solving boundary value problems for the Laplace equation in bounded domains. Representation of the solution as a series of eigenfunctions satisfying homogeneous boundary conditions on a portion of the boundary. Finding the coefficients of a series of non-homogeneous boundary conditions. The Dirichlet problem with a given function value at the boundary. The Neumann problem with a given normal derivative at the boundary. Examples of solutions for a circle, rectangle, and ring.	LC, SC
Section 2	Methods for solving equations of mathematical physics	2.1	Methods of potential theory	Potential theory methods as a way to represent solutions of elliptic equations through integrals of sources distributed over a boundary or volume. Single-layer potential with sources distributed over the surface. Double-layer potential with dipoles distributed over the surface. Volume potential from distributed sources within a domain. Reduction of boundary value problems to integral equations for the potential density.	LC, SC
		2.2	Numerical methods	Numerical methods as approaches to the approximate solution of mathematical physics equations using computational algorithms. Finite difference method with replacement of derivatives by difference relations on a grid. Finite element method with partitioning of the domain into small elements and approximation of the solution by piecewise polynomial functions. Boundary element method for problems with constant coefficients in unbounded domains. Error estimation and convergence of numerical methods.	LC, SC
		2.3	Variational methods	Variational methods as methods for reducing a boundary value problem to the problem of minimizing a certain functional. Energy functional for elliptic equations. The principle of minimum potential energy for equilibrium states. The Ritz method for finding	LC, SC

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
				the minimum of a functional on a finite-dimensional subspace of test functions. The relationship of variational methods to the finite element method. Natural boundary conditions arising from a variational formulation.	
		2.4	Projection methods	Projection methods as approximate solutions to equations based on projecting the equation onto a finite-dimensional subspace. The Galerkin method, requiring the residual to be orthogonal to all test functions. The least-squares method, minimizing the squared residual. The collocation method, which makes the equation vanish at given points. Selecting basis functions with consideration of boundary conditions.	LC, SC
		2.5	Asymptotic methods	Asymptotic methods as methods for obtaining approximate solutions for small or large parameter values. Perturbation theory for problems with a small parameter at the highest derivative or on the right-hand side. Regular perturbations with expansion of the solution in powers of the small parameter. Singular perturbations with the appearance of boundary layers near the boundaries. The method of matched asymptotic expansions for constructing a uniformly valid approximation.	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. Tikhonov A.N. Samarsky A.A. Equations of mathematical physics
2. Aramanovich I.G., Levin V.I. Equations of Mathematical Physics. Moscow: Nauka. 1976.
3. Savin A.Yu. Sternin B.Yu. Equations of mathematical physics. Presentation. RUDN University 2012
4. Kirillov A.I. (ed.) - Solution book. Higher Mathematics. Special sections, 2nd ed., FML, 2006
5. Korshunov Yu.S., Rynovskaya M.V., Savin A.Yu. Equations of mathematical physics. M. RUDN University. 2016.

Further reading:

1. Farlow C. Partial Differential Equations for Scientists and Engineers. Moscow: Mir. 1985
2. E. Zauderer Partial differential equations and applied mathematics. 2006
3. Agoshkov V. I., Dubovsky P. B., Shutyaev V. P. Methods for solving problems of mathematical physics / Ed. G. I. Marchuk. - M.: FIZMATLIT, 2002. - 320 p. - ISBN 5-9221-02457-5

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
 - Electronic library system of RUDN - ELS RUDN <http://lib.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
- Electronic Library System "Troitsky Bridge"

2. Databases and search engines

- electronic fund of legal and regulatory documentation <http://docs.cntd.ru/>
- Yandex search engine <https://www.yandex.ru/>
- Google search engine <https://www.google.ru/>
- SCOPUS abstract database <http://www.elsevier.com/locate/scopus/>

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

1. Lecture course on the subject "Equations of Mathematical Physics".

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

DEVELOPERS:

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