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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

DIFFERENTIAL EQUATIONS

(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 "Differential Equations" 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 semesters 3 and 4 of the second year. The course is offered by the Department of Mechanics and Control Processes. It consists of 8 sections and 11 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 "Differential Equations" 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-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; |
| GPC-4 | Capable of evaluating the effectiveness of management systems developed using mathematical methods | GPC-4.1 Knows the basic requirements of information security, existing information communication technologies; GPC-4.2 Able to solve professional tasks using information and communication technologies and taking into account the basic requirements of information security; GPC-4.3 Possesses the skills to use existing information technologies to solve problems of professional activity; |

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

Discipline "Differential Equations" 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 "Differential Equations".

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 | 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; | Research work / Scientific research work; Technological Training; Undergraduate Training; Space Flight Mechanics; Numerical Methods; Automatic Control Theory; Equations of mathematical physics; Optimal Control Methods; Analysis of Geoinformation Data; |
| GPC-4 | Capable of evaluating the effectiveness of management systems developed using mathematical methods | | Analysis of Geoinformation Data; Research work / Scientific research work; 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 “Differential Equations” is 7 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 | 4 |
| <i>Contact work, academic hours</i> | 123 | | 72 | 51 |
| Lectures (LC) | 53 | | 36 | 17 |
| Laboratory work (LW) | 0 | | 0 | 0 |
| Practical/seminar classes (SC) | 70 | | 36 | 34 |
| <i>Independent work of students, academic hours</i> | 102 | | 45 | 57 |
| <i>Control (exam/test with assessment), academic hours</i> | 27 | | 27 | 0 |
| Total complexity of the discipline | academic hours | 252 | 144 | 108 |
| | credit | 7 | 4 | 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 | First-order differential equations | 1.1 | Integration of differential equations with separable variables and differential equations. Integration of homogeneous differential equations. | The concept of a first-order differential equation resolved with respect to the derivative. Equations with separable variables: the method of separation of variables and subsequent integration. Homogeneous differential equations: definition and method of reduction to an equation with separable variables by replacing the desired function. | LC, SC |
| | | 1.2 | Linear differential equations of the first order. Integration of linear differential equations. | The structure of a first-order linear differential equation. The method of variation of an arbitrary constant (Lagrange's method). The Bernoulli method (representing the solution as a product of two functions). The general solution of a linear inhomogeneous equation as the sum of the general homogeneous solution and a particular inhomogeneous solution. | LC, SC |
| | | 1.3 | Equations unresolved with respect to the derivative. General method for introducing a parameter. Lagrange and Clairaut equations. | Differential equations not resolved with respect to the derivative. A general method for introducing a parameter for their solution. The Lagrange equation: structure, method of reducing to a linear equation using parameterization. The Clairaut equation as a special case of the Lagrange equation, and its general and special solutions. | LC, SC |
| Section 2 | Higher order equations and systems of equations | 2.1 | Integrable cases of high-order equations (equations that admit reduction of order). | Differential equations of order higher than first. The main types that admit reduction in order are: equations that do not contain the unknown function; equations that do not contain an independent variable; equations that are homogeneous with respect to the function and its derivatives. Methods of successive reduction of order and reduction to first-order equations. | LC, SC |
| | | 2.2 | Solution of systems of differential equations by reducing them to higher-order equations | Normal systems of differential equations. The method of eliminating unknown functions. Reducing the system to a single higher-order differential equation with respect to one of the functions. Solving the resulting equation and finding the remaining functions from the original system. | LC, SC |
| Section 3 | Existence and uniqueness theorems | 3.1 | Lipschitz condition. A theorem for the existence and uniqueness of a solution to the Cauchy problem in a bounded domain and in a strip | The concept of the Lipschitz condition for a function on the right-hand side of a differential equation. Its connection with continuity and differentiability. Formulation and content of the existence and uniqueness theorem for a solution to the Cauchy problem for a first-order differential equation. Conditions of the theorem in a | LC, SC |

| Section number | Name of the discipline section | Topic Title | | Topic Contents | Type of academic work* |
|----------------|---|-------------|---|--|------------------------|
| | | | | bounded domain and in an infinite strip. Practical significance of the theorem for the correctness of mathematical models. | |
| Section 4 | Approximate-analytical and numerical methods for solving the Cauchy problem | 4.1 | Method of successive approximations. Method of power series. Method of small parameter. Numerical methods | Picard's method of successive approximations: constructing a recurrent sequence of functions converging to an exact solution. Power series method: representing a solution as a power series and finding its coefficients. Small parameter method (perturbation theory) for equations containing a small parameter. Numerical methods: grid concepts, discretization. Explicit and implicit methods (Euler's method, Runge-Kutta methods). Their accuracy and stability. | LC, SC |
| Section 5 | Boundary value problems. | 5.1 | Green's function method. Approximate analytical methods for integrating boundary value problems. | Statement of boundary value problems for ordinary differential equations. Difference from the Cauchy problem. The concept of the Green's function as a kernel, allowing the solution of a boundary value problem to be represented in integral form. Construction of the Green's function for linear boundary value problems. Approximate analytical methods: Galerkin's method, Ritz's method. Variational principles and their application. | LC, SC |
| Section 6 | Elements of the qualitative theory of differential equations. | 6.1 | Singular points of second-order linear autonomous dynamic systems. Phase plane method. | Autonomous systems of differential equations. The concept of phase space and phase trajectories. The phase plane method for second-order systems. Classification of singular points of linear systems: node, saddle, focus, center. Their nature (stability, instability). Phase portraits and their analysis. | LC, SC |
| Section 7 | Stability of solutions of linear equations and systems. | 7.1 | The concept of stability of solutions. Lyapunov and Chetaev's theorem. | The concept of Lyapunov stability: stability, asymptotic stability, instability. Investigation of the stability of solutions to linear systems with constant coefficients. Lyapunov's theorem on stability to the first approximation. Chetaev's theorem on instability. Lyapunov functions (definitely positive, constant-sign) as a method for studying the stability of nonlinear systems. | LC, SC |
| Section 8 | First-order partial differential equations | 8.1 | Nonlinear systems. First-order partial differential equations. | Linear and nonlinear first-order partial differential equations. The method of characteristics for solving linear equations. Characteristic curves. Solution of the Cauchy problem for first-order equations. Complete, general, and singular integrals of nonlinear equations (the Hamilton-Jacobi equation). The concept of systems of first-order partial differential equations. | 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. | Projector |
| 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. Filippov A.F. Introduction to the Theory of Differential Equations. - M.: Lenland, 2013
2. Filippov A.F. Collection of problems in differential equations. - M.: Librokom, 2012.
3. Krasnov M.L., Kiselev A.I., Makarenko G.I. Collection of problems in ordinary differential equations. - M.: Librokom, 2013

Further reading:

1. Fedoryuk M.V. Ordinary differential equations. - M.: Librokom, 2012.
2. Elsgolts L.E. Differential equations. - M.: Publishing house LCI, 2013.
3. Stepanov V.V. Course of differential equations. - M.: LCI Publishing House, 2008.

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.elsevierscience.ru/products/scopus/>

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

1. Lecture course on the subject "Differential equations".

* - 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:

Associate Professor

Position, DEPARTMENT

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