Federal State Autonomous Educational Institution of Higher Education
«RUDN University»

Engineering Academy

WORKING PROGRAM OF THE DISCIPLINE

Name of the discipline

Technology and engineering of nanodevices and systems

Recommended for the educational program

01.06.01 Mathematics and Mechanics

Focus of the program (profile)
Dynamics and strength of machines, devices and equipment» (technical sciences)

1. Aims and objectives of the discipline

The aim of the course is to form professional competences in the field of scientific research on technology and engineering of nanodevices and systems in postgraduate students of " Dynamics and strength of machines, devices and equipment» (technical sciences)" profile. Formation of professional outlook on the state, problems and prospects of development of modern technology and engineering of nanodevices and systems, taking into account scientific and technical achievements in the field of related sciences. Study of modern analytical methods and approaches for solving problems of control of such systems: formation of ideas about technology and engineering of nanodevices and systems as a fundamental science and universal language of natural sciences, general engineering and professional disciplines; acquisition of abilities and skills to apply technical means and methods of technology and engineering of nanodevices and systems to solve applied professional problems using scanning probe equipment, studying electronics of such equipment

Objectives of the course are to teach students to find and comprehend new, as well as rethink modern technology and engineering of nanodevices and systems: to make students understand nanotechnology as a systemic basis for building the 6th technological pattern; to strengthen students' understanding of the key role of modern nanodevices and systems technology in providing effective professional activity; to form an idea of theoretical, technical and organisational aspects of using modern nanodevices technology

2.Place of the discipline in the structure of the curriculum

The discipline "Technology and engineering of nanodevices and systems" refers to the variable part of block 1 of the curriculum.

Table 1 shows the previous and subsequent disciplines aimed at the formation of discipline competencies in accordance with the competence matrix of EP HE.

Table № 1

Prior and subsequent disciplines aimed at the formation of competencies

№	Code and name of competence	Preceding disciplines	Subsequent disciplines (groups of disciplines)
Universal competences			
1	ability to critically analyze and evaluate modern scientific achievements, generate new ideas when solving research and practical problems, including interdisciplinary areas (UC-1)	History and philosophy of science Dynamics and strength of machines, devices and equipment	
General professional competencies			
2	ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies (GPC-1)	Research methodology Priority areas for the development of mathematics and mechanics Dynamics and strength of machines, devices and equipment	
Professional competence			
3	willingness to apply promising research methods and solve professional problems, taking into	Research methodology Priority areas for the development of	

	account global trends in the development of technical objects for various purposes (PC-1)	mathematics and mechanics Dynamics and strength of machines, devices and equipment	
4	ability to identify the essence of scientific and technical problems arising in the course of professional activity, and to apply the physical and mathematical apparatus, theoretical, computational and experimental research methods, methods of mathematical and computer modeling, for solving the previously mentioned problems (PC-2)	Research methodology Dynamics and strength of machines, devices and equipment	
5	willingness to carry out research work and solve scientific and technical problems in the field of applied mechanics based on the achievements of engineering and technology, classical and technical theories and methods, physical-mechanical, mathematical and computational models that have a high degree of adequacy to real processes, machines and structures (PC-3)	Research methodology Priority areas for the development of mathematics and mechanics Dynamics and strength of machines, devices and equipment	
6	ability to create new generations of machines, devices, equipment, technologies and materials with qualitatively new functional properties, as well as to improve existing machines, devices, equipment and technologies with improved performance characteristics, less material and energy consumption (PC-4)	Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using informatics and computer technology in higher education Dynamics and strength of machines, devices and equipment	
7	ability to develop methods of mechanics and computational mathematics, computer technology and	Fundamentals of teaching methods for the development of engineering applications	

	decision support systems in scientific research, design and engineering activities (PC-5)	based on mathematical modeling using informatics and computer technology in higher education Dynamics and strength of machines, devices and equipment	
8	ability to study patterns and relationships, dynamic processes, stress states and strength of machines, devices and equipment (PC-6).	Priority areas for the development of mathematics and mechanics Fundamentals of teaching methods for the development of engineering applications based on mathematical modeling using informatics and computer technology in higher education Dynamics and strength of machines, devices and equipment	

3. List of intended learning outcomes of the discipline

Universal competences	
UC-1	ability to critically analyze and evaluate modern scientific achievements, generate new ideas when solving research and practical problems, including in interdisciplinary fields
General professional competencies	
GPC-1	the ability to independently carry out research activities in the relevant professional field using modern research methods and information and communication technologies
Professional competences	
PC-1	willingness to apply promising research methods and solve professional problems, taking into account global trends in the development of technical objects for various purposes
PC-2	the ability to identify the essence of scientific and technical problems arising in the course of professional activity, and to apply for their solution the physical and mathematical apparatus, theoretical, computational and experimental research methods, methods of mathematical and computer modeling
PC-3	readiness to carry out research work and solve scientific and technical problems in the field of applied mechanics based on the achievements of engineering and technology, classical and technical theories and methods, physical and mechanical, mathematical and computer models that have a high degree of adequacy to real processes, machines and structures

PC-4	the ability to create new generations of machines, devices, equipment, technologies and materials with qualitatively new functional properties, as well as to improve existing machines, devices, equipment and technologies with increased operational characteristics, less material and energy consumption
PC-5	ability to develop methods of mechanics and computational mathematics, computer technology and decision support systems in scientific research, design and engineering activities
PC-6	the ability to study patterns and relationships, dynamic processes, stress states and strength of machines, devices and equipment

As a result of the discipline, the postgraduate student should:

Knowledge of the main modern methods of implementing technology and engineering of nanodevices and systems, current scientific literature and journal articles in the periodical press dealing with such problems.

Identify current current theoretical problems in the technology and engineering of nanodevices and systems and, on this basis, explain existing facts and processes in the development of technology and engineering of nanodevices and systems.

To find and comprehend new, as well as rethink previously known facts, processes and trends that characterise the formation, evolution and transformation of nanodevices and systems technology and engineering in a historical retrospective.

4 The scope of the discipline and types of study:

The course consists of **3 credit units (108 hours).**

Type of study	**Total hours**	**Semester**
		4
Classroom activities (total)	**20**	20
Including:		
Lectures	**-**	-
Practical exercises (PP)	**20**	20
Seminars (C)	**-**	-
Laboratory work (LW)	**-**	-
Independent work (total)	**88**	88
Monitoring	**-**	-
Total time commitment per hour	**108**	108
credit unit.	**3**	3

5. Content of the discipline

5.1 Content of the sections of the discipline

Main sections of the discipline: Topical issues of technology and engineering of nanodevices and systems. Current issues in technology and engineering of nanodevices and systems. Current issues in technology and engineering of nanodevices and systems.

No. n/a	Name section disciplines	Contents of the section
1	Current challenges in the technology and engineering of nanodevices and systems.	A nanoscale world. The tools of nanotechnology. Probe microscopy. Nanolaboratories and nanofabs. Nanomaterials. Monoatomic nanomaterials. Graphene. Silicene-2D silicon. Other monoatomic materials. Quantum electrodynamics and 2D materials. Dirac fermions. Classical Hall effect. Quantum Hall effect. Graphene. Quasi-particles. Interaction of atoms in graphene. Integral overlap. Bilinear half-metal. Spin and pseudospin current carriers. Ambipolarity. Wave equations. Quantum physics operators. Dualism. Wave function. Schrödinger wave equation. Particle in time. Spatial wave.
2	Current issues in the technology and engineering of nanodevices and systems.	Dirac matrices and fermions. Dirac alpha matrices. Pauli matrices. The Hamiltonian of graphene. Continuous linear spectrum. The wave function for K-domain. Nanocarbon. Carbon and its nanoalloys. Nanocarbon. Four orbitals. Inhomogeneities in hexagonal meshes. Graphene nanoribbons. Edges of hexagonal meshes. Ideal nanoribbons. Carbon nanotubes. Chirality. Indices. Single and multilayer nanotubes. Smallest and largest diameters. Fraction of surface atoms. Electronic structures. Technological methods. Nanotubes (NT) of inorganic substances. Nanotubes based on boron nitride. Nanotube-diode. Fullerenes. Morphology of fullerenes.
3	Current problems in technology and engineering of nanodevices and systems.	Convergent nanocircuitry. Millimetre nanoelectronics. Graphene transistors. First graphene IC. Alternative. Memristor as a universal element. Other membrane elements. New architecture. Memristor CMOS IC. Neuron, memristor, model. Memristor - the basis for AI systems. Ambipolar circuitry. Ambipolarity - new quality of circuitry. Electron filtration.

5.2 Sections of the disciplines and types of classes

No. n/a	Name of discipline section	Lectz.	Prakt. zan.	Lab.	Semin	SRS	All-hour.
1.	Current challenges in the technology and engineering of nanodevices and systems.		6			20	36
2.	Current issues in the technology and engineering of nanodevices and systems.		6			30	36
3.	Current problems in technology and engineering of nanodevices and systems.		8			28	36
	TOTAL		20			88	108

6. Laboratory workshop - not foreseen

7. Practical exercises

No. n/a	Discipline	Topics of practical exercises	Labour input

	section no.		(hours)
1.	1	The tools of nanotechnology. Probe microscopy.	2
2	1	Nanolaboratories and nanofabs. Nanomaterials. Monoatomic nanomaterials.	2
3	1	Graphene. Silicene-2D silicon.	2
4	2	Carbon and its nanoalloys. Nanocarbon. The four orbitals. Inhomogeneities in hexagonal meshes.	2
5	2	Graphene nanoribbons. Edges of hexagonal meshes. Ideal nanoribbons. Carbon nanotubes.	2
6	2	Chirality. Indices. Single and multilayer nanotubes.	2
7	3	. Memristive CMOS IC. Neuron, memristor, model.	2
8	3	The memristor is the backbone of AI systems.	2
9	3	Ambipolar circuitry. Ambipolarity is a new quality of circuitry.	2
10	3	Electron filtration.	2

8. Types of independent work

No. n/a	Discipline section no.	Topics for independent work	Labour input (hours)
1.	1	Reviewing scientific conference proceedings in Russian and English to identify the most topical research issues in the physical and mathematical sciences	15
2	1	Preparation of articles on the subject of the thesis research	15
3	2	Preparing scientific papers at regional, national and international conferences	15
4	2	Development of research projects and participation in regional, national and international competitions in the technical sciences	15
5	3	Preparation of materials for participation in grants awarded to postgraduate students and young scientists in Russia and abroad in the technical sciences	14
6	3	Preparing and running a research seminar, a methodological seminar or a master class.	14

9. Educational and methodological and informational support of the discipline:

(a) Basic literature

1. Gubin S. P., Tkachev S. V. Grafen i rodstvennyye nano formy ugleroda. Knizhnyy dom "LIBROKOM". 2012 g.

b) further literature

1. Diveyev A. I., Cofronova Ye. A. Metod setevogo operatora i yego primeneniye v zadachakh upravleniya. M.: Izd-vo RUDN, 2012. – 182 s.
2. Samarskiy A. A., Vabishchevich P. N. Chislennyye metody resheniya obratnykh zadach matematicheskoy fiziki: Uchebnoye posobiye. - M.: Izd-vo LKI, 2014. - 480 s.

3. Naats V. I., Naats I. E. Matematicheskiye modeli i chislennyye metody v zadachakh ekologicheskogo monitoringa atmosfery: Monografiya - M.: FIZMATLIT, 2010. - 328 s.
4. Rumyantsev A. V. Metod konechnykh elementov v zadachakh teploprovodnosti: Uchebnoye posobiye - Kaliningrad: Izd-vo KGU, 1995. - 170 s.:
5. Sveshnikov A. G. i dr. Lineynyye i nelineynyye uravneniya sobolevskogo tipa - M.: Fizmatlit, 2007. - 736 s.

c) Software: only licensed software installed at PFUR is used. Microsoft Office software package and specialised software Dev-C++, Scilab.

d) databases, reference and retrieval systems

Russian State Library Digital Library http://www.rsl.ru/

PFUR Library website http://lib.rudn.ru/

Science Direct http://www.sciencedirect. Description: This resource contains a collection of scientific, technical full-text and bibliographic information. A multidisciplinary database of scientific journals in the exact and technical sciences.

EBSCO http://search.ebscohost.com, Academic Search Premier (a comprehensive database containing information on the humanities and the natural sciences).

Oxford University Press http://www3.oup.co.uk/jnls. Oxford University Press Science and Engineering journals in the HSS collection

Sage Publications http://online.sagepub.com . The Sage Publications database includes journals from a variety of disciplines: Sage_STM - over 100 journals in science, engineering and technology.

Springer/Kluwer http://www.springerlink.com. The journals and books from Springer/Kluwer cover different fields of knowledge and are divided into subject categories.

Tailor & Francis http://www.informaworld.com . The magazine collection has over 1,000 titles in all fields of knowledge.

American Mathematical Society http://www.ams.org/ Resource of the American Mathematical Society.

European Mathematical Society http://www.euro-math-soc.eu/ European Mathematical Society Resource.

Portal to Mathematics Publications http://www.emis.de/projects/EULER/

Catalogue of mathematical Internet resources http://www.mathtree.ru/.

Zentralblatt MATH (zbMATH) https://zbmath.org

All-Russian mathematics portal mathnet.

Web of Science http://www.isiknowledge.com

Resources of the Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences (ISIS RAS) http://elibrary.ru.

University Information System RUSSIA. http://www.cir.ru/index.jsp.

Gosts system of standards for information, librarianship and publishing http://www.ifap.ru/library/gost/sibid.htm

PFUR Digital Library http://www.rsl.ru/

e) periodicals

- Algebra and analysis
- Discrete mathematics
- Journal of Computational Mathematics and Mathematical Physics
- Proceedings of the Russian Academy of Sciences. Mathematical Series
- Mathematical notes
- A mathematical compendium
- Mathematical modelling
- Theoretical and mathematical physics
- Probability theory and its applications
- Advances in mathematical sciences

- Functional analysis and its applications
- Computer science and its applications
- Problems of information transfer
- Informatics systems and tools
- Proceedings of the V.A. Steklov Mathematical Institute
- Mathematical issues in cryptography
- Current problems in mathematics
- Computational methods and programming
- Proceedings of the I. G. Petrovsky Seminar
- Scientific Notes of Moscow State University
- Fundamental and applied mathematics

10. Material and technical support of the discipline:

Moscow, Ordzhonikidze street, 3, bld. 1, 5. Multimedia classrooms 496, 496a, 493 equipped with a video projector and a laptop with presentation software and internet access.

11. methodological guidelines for organising the study of the discipline:

11.1 Guidelines for postgraduate students.

In practical classes of the discipline there are control activities to identify the obtained knowledge, skills and competences. In the framework of independent work postgraduate students study educational-methodical support of the discipline, prepare homework, work on questions and assignments for self-study, search and review scientific publications and electronic sources of information. Independent work must be systematic and controlled by the teacher, taken into account by the teacher for grading.

In order to improve the quality of the discipline, the postgraduate student should prepare for a lecture, as it is the leading form of organisation of student learning and realises the functions that contribute to it:

- to form the basic concepts of the discipline,
- stimulate interest in the discipline and its topics of study,
- The main objective is to systematise and structure the whole body of knowledge in the discipline,
- orientation in the scientific literature revealing the problems of the discipline.

The preparation for the lecture is as follows:

- study of the material from the previous lecture,
- Analysis of the topic of the forthcoming lecture (from the thematic plan, from the lecturer's information),
- familiarise yourself with the teaching material in the textbook and teaching aids,
- analyse the place of the topic under study in their professional training,
- prepare questions to ask the lecturer during the lecture.

Preparing for the practical exercises:

- The training session plan: first the main questions, then the discussion questions, assessing the scope of the assignment;
- Study the lecture notes on the topic of the practical session, selecting the material necessary for the study of the questions posed;
- Familiarisation with the recommended basic and additional literature on the topic, and new publications in periodicals;

- To highlight the main concepts of the topic, which will contribute to an effective mastery of the discipline;
- Prepare an abstract or mini-abstract that can be used for public speaking in class.

You can use the syllabus in terms of objectives, list of knowledge, skills, terms and training issues as a guide for the organisation of your studies.

Preparing for a test. It is necessary to prepare for the test in a purposeful, regular, systematic manner and from the first days of study in the discipline. At the very beginning of the discipline the postgraduate student gets acquainted with the discipline programme, the list of knowledge and skills that the postgraduate student should possess, control activities, textbook, textbooks on the discipline studied, electronic resources, the list of questions for the test.

Systematically completing the coursework in lectures, practical classes and tutorials will enable you to successfully master the discipline and create a good basis for passing the examination.

Postgraduate students are required to attend classes, complete the assignments of the Head of Discipline, get acquainted with the recommended literature and prepare an essay for the round table (the choice of essay topic is made in consultation with the Head of Discipline and academic supervisor). Postgraduate students carry out projects, creative tasks for independent work, taking into account the profile of the disciplines that will be implemented by them during the industrial practice. The results of independent work assignments are evaluated on the basis of the grade-rating and are reflected in the educational route of the postgraduate student. During the attestation of postgraduate student the quality of work in the classroom (ability to conduct a scientific discussion, the ability to clearly and concisely formulate his thoughts), the level of preparation for independent research activities of a specialist in the field of pedagogy of higher education, history of pedagogy and education, the quality of assignments (presentations, reports, analytical papers, etc.) are evaluated.

11.2 Guidelines for teachers.

In the process of teaching the discipline "Technology and engineering of nanodevices and systems" the teacher should pay special attention to the organisation of practical classes and monitor the independent work of postgraduate students. In the process of mastering the discipline postgraduate students should be focused not only on active mastering of the set of pedagogical knowledge, but also on the ability to creatively apply it in practice, extrapolating to the modern educational process in higher education.

While studying the section 1 "Current problems of technology and engineering of nanodevices and systems" the teacher should pay attention of postgraduate students to the content of categorical apparatus of the discipline, its interrelation with other concepts. It is important to consider in practical classes the applied possibilities of applying various research methods.

Lectures should involve postgraduate students in discussions that address current scientific issues in the field of computer science and computing.

The content of section 2 "Topical issues of technology and engineering of nanodevices and systems" is mastered in lectures and practical classes. Work in practical classes should be aimed at active mastering of the set of theoretical knowledge, emphasising the peculiarities of the content of the stages of scientific research. The teacher should orient the postgraduate students to the ability to organise and conduct various types of scientific research in computer science and computer engineering.

In mastering the content of section 3 "Current problems of technology and engineering of nanodevices and systems" the teacher uses a variety of technologies and forms of classes and creates conditions for postgraduate students to demonstrate communication skills, readiness to lead a discussion on scientific problems.

The interim assessment evaluates the quality of postgraduate students' mastery of basic research categories, their ability to use knowledge to solve scientific problems and their readiness to actualise scientific competence in the actual research process of the university, scientific organisation, etc.

11.3 Assessment tools for assessing the mastery of the competence.

Compliance of grading systems (previously used grades of final academic achievement, ECTS grades and grading-rating system (GRS) of assessments of current progress) (In accordance with the Rector's Order No. 996 of 27.12.2006)

BRS scores	Traditional assessments in the RF	Scores for transferring grades	Assessments	ECTS grades
86 - 100	5	95 - 100	5+	A
		86 - 94	5	B
69 - 85	4	69 - 85	4	C
51 - 68	3	61 - 68	3+	D
		51 - 60	3	E
0 - 50	2	31 - 50	2+	FX
		0 - 30	2	F

A	***"Excellent"*** - the theoretical content of the course has been fully mastered without any gaps, the necessary practical skills to work with the mastered material have been formed, all the learning tasks in the study programme have been completed, the quality of their implementation is assessed with a number of points close to the maximum**.**
B	***"Very good"*** - the theoretical content of the course has been fully mastered without any gaps, the necessary practical skills to work with the mastered material have been mostly formed, all the learning tasks in the curriculum have been completed, the quality of most of them has been assessed as close to the maximum number of points.
C	***"Good"*** - the theoretical content of the course has been fully mastered without any gaps, some practical skills in working with the mastered material have been insufficiently formed, all the learning tasks in the curriculum have been completed, none of them has been assessed with a minimum score, some types of tasks have been completed with mistakes**.**
D	***"Satisfactory"*** - the theoretical content of the course has been partly mastered, but the gaps are not significant, the necessary practical skills to work with the mastered material have been mostly formed, most of the curriculum tasks have been completed, some of the completed tasks may contain mistakes.
E	***"Intermediate"*** - the theoretical content of the course has been partly mastered, some practical work skills have not been developed, many of the curricular tasks have not been completed, or the quality of some of them has been assessed as close to the minimum number of points.

FX	***"Conditionally unsatisfactory"*** - the theoretical content of the course has been partially mastered, the necessary practical work skills have not been formed, most of the learning tasks in the curriculum have not been completed or the quality of their completion is assessed as close to the minimum; with additional independent work on the course material, the quality of completion of the learning tasks can be improved.
F	***"Absolutely unsatisfactory"*** - the theoretical content of the course has not been mastered, the necessary practical work skills have not been formed, all completed assignments contain gross errors, additional independent work on the course material will not lead to any meaningful improvement in the quality of the course assignments.

12. Assessment toolkit.

12.1 Issues to be examined at the mid-term evaluation (topic 1).

1. A nanoscale world. The tools of nanotechnology.
2. Probe microscopy.
3. Nanolaboratories and nanofabs. Nanomaterials.
4. Monoatomic nanomaterials.
5. Graphene. Silicene-2D silicon. Other monoatomic materials.
6. Quantum electrodynamics and 2D materials.
7. Dirac fermions.
8. The classic Hall effect. The quantum Hall effect.
9. Graphene. Quasi-particles. Interaction of atoms in graphene.
10. Integral overlap. Double lined half-metal.
11. Spin and pseudospin current carriers.
12. Ambipolarity.
13. Wave equations. Quantum physics operators. Dualism. Wave function. Schrödinger wave equation. Particle in time. Spatial wave.

12.2 Questions to be taken for credit (topics 2 and 3).

1. Dirac matrices and fermions. Dirac alpha matrices. Pauli matrices. The Hamiltonian of the graphene.
2. Continuous linear spectrum.
3. Wave function for the K-valley.
4. Nanocarbon. Carbon and its nanoallotropes.
5. Nanocarbon. Four orbitals.
6. Inhomogeneities in hexagonal meshes.
7. Graphene nanoribbons. Edges of hexagonal meshes.
8. Perfect nanoribbons.
9. Carbon nanotubes.
10. Chirality. Indices.
11. Single and multilayer nanotubes.
12. The smallest and largest diameters. Fraction of surface atoms.
13. Electronic structures. Technological methods.
14. Nanotubes (NTs) of inorganic substances.
15. Nanotubes based on boron nitride. Nanotube diode. Fullerenes.
16. Morphology of fullerenes.
17. Convergent nano-circuitry.

18. Millimetre nanoelectronics.
19. Graphene transistors.
20. The first graphene IC. Alternative.
21. The memristor as a universal element. Other memristor elements.
22. New architecture. Memristive CMOS IC.
23. Neuron, memristor, model.
24. The memristor is the backbone of AI systems.
25. Ambipolar circuitry. Ambipolarity is a new quality of circuitry.
26. Electron filtration.

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