NJSC ''Kazakh National Research Technical University after K.I. Satpayev''
Institute of Industrial Engineering named after A. Burkitbayev
Department of Engineering Physics

EDUCATIONAL PROGRAM

"APPLIED AND ENGINEERING PHYSICS"
Doctor of Philosophy (PhD)

Based on the following specialty of the invalidated Classifier of specialties: "6D074000 – Nanomaterials and nanotechnology"
"6D072300 - Technical Physics"

1st edition
in accordance with the State Educational Standard of Higher Education 2018

Almaty 2019

The program was drawn up and signed by the parties:
From KazNRTU named after K. Satpayev:
1. Head of EP Department _____ R.E. Beisenov
2. Director of Institute of IE _____ B.O. Omarbekov
3. Chairman of Sc. Method. Council of EP Department _____ Kh.R. Maylina

From employers:

LLP «Institute of Physics and Technology» _____ A.S. Serikkanov

Approved at a meeting of the Educational and Methodological Council of the Kazakh National Research Technical University named after K. Satpayev. Protocol №15 from 06.06.2019.

Qualification:
Level 8 of the National Qualifications Framework:
8D05 Natural sciences, mathematics and statistics
8D053 Physical sciences

Professional competence:
Possession of scientifically grounded methodology of theoretical and experimental research in the field of physics of functional materials. Possession of the culture of scientific research, including using the latest information and communication technologies. Ability to develop and use modern methods of scientific research and their application in independent research activities; readiness to organize the work of the research team in professional activities; readiness for teaching activities in the basic educational programs of higher education.

Short description of the program

Designed for scientific and pedagogical training of doctors of philosophy (a PhD) in the educational program (EP) **"Applied and Engineering Physics."**

The program is designed to train qualified specialists with deep theoretical and practical knowledge in the field of physics of functional materials, devices and systems, the performance of which is determined by low-dimensional effects and principles of functioning. The obtained professional competencies allow graduates to realize themselves in various types of activities, such as research and innovation, design and engineering, design and technological, organizational and management.

Graduates of this educational program are prepared to work in research institutes, higher educational institutions, at enterprises of heavy, light, mining, metallurgy, aviation, space industries, in the construction and machine-building sectors of the economy, in the creation of new composite and functional materials.

A specialist who has mastered the educational program of doctoral studies in the direction of "Applied and Engineering Physics" must have advanced knowledge in the field of work or research, based on a critical understanding of theories and principles. The person skilled in the art must have the skills and abilities that demonstrate the skill and innovation required to solve complex and unpredictable problems in the physics of functional materials. His competence should be sufficient to manage complex technical or professional activities or projects with responsibility for making decisions in unpredictable contexts of work or research. He must be able to take responsibility for guiding the professional development of individuals and groups.

Awarded academic degree / qualification: "Doctor of Philosophy (PhD) in the direction of Applied and engineering physics."

1 Purpose (mission) of the educational program

The purpose of studying this educational program is

- the acquisition of knowledge about the structure and properties of functional materials, manufacturing techniques and methods of investigation of low-dimensional structures, sufficient for an understanding of a variety of applications;
- providing fundamental training for PhD PhD students for their successful solution of scientific and engineering problems in the field of physics of functional materials;
- develop the skills of PhD students of engineering analysis and design, productions and research, including as a director or member of the team;
- to prepare PhD students for a successful career in academic, scientific and industrial organizations and institutions involved in the decision by the development of functional materials physics problems have professional and ethical responsibility, the ability to self-learn and improve skills for life.

2 Types and subjects of professional activity

- scientific and pedagogical;
- research;
- organizational and management;

- design and engineering

3 Objects of professional activity:

- organization of secondary education of all types and types, regardless of the form of ownership and departmental subordination;
- organization of technical and vocational education;
- higher education institutions;
- research institutes;
- institutes for advanced training and retraining of employees of the education system;
- authorized and local executive bodies in the field of education.

PASSPORT OF THE EDUCATIONAL PROGRAM

1 The scope and content of the program

The educational program for the preparation of a Doctor of Philosophy (PhD) has a scientific and pedagogical focus and involves fundamental educational, methodological and research training and in-depth study of disciplines in the relevant areas of science for the system of higher and postgraduate education and the scientific sphere.

The educational program for the training of a doctor in the profile assumes fundamental educational, methodological, research training, and in-depth study of disciplines in the relevant areas of science for the branches of the national economy, the social sphere: education, medicine, law, art, economics, business administration and in the field of national security and military affairs.

Educational programs for doctoral studies in terms of vocational training was developed based on studying the experience of foreign universities and research centers that implement accredited training programs for PhD doctors or doctors by profile.

The content of the educational program of specialized doctoral studies is established by the university independently.

The main criterion for the completeness of the educational process for the preparation of doctors of philosophy (PhD) (doctor by profile) is the mastering by a PhD student of at least 180 academic credits, including all types of educational and scientific activities.

The term of study in doctoral studies is determined by the amount of acquired academic credits. With the development of the established amount of academic credits and the achievement of the expected learning outcomes for obtaining a Doctor of Philosophy (PhD) degree or by profile, the doctoral educational program is considered fully mastered.

The training of personnel in doctoral studies is carried out based on educational master's programs in two areas:

1) Scientific and pedagogical study for at least three years;

2) The profile study for at least three years.

Content of the educational program

The combination of deep fundamental knowledge in the field of physics of low-dimensional systems, physical materials science, modern technologies and functional materials, information technologies with the skills of working on complex technological and research equipment of the world level, along with deep general cultural training, allows graduates of the educational program of doctoral studies (PhD) in the direction " Applied and Engineering Physics "to solve complex research, development, technological and expert problems both when working as part of research groups under the leadership of leading scientists, and when working in the structure of leading domestic enterprises.

The provisions of this educational program of doctoral studies (PhD) in the direction of "Applied and Engineering Physics" - achieving high quality postgraduate professional education in compliance with the mandatory requirements for the level of training of PhD students;

- Creation of a system for monitoring the effectiveness of the work of higher educational institutions and research organizations that train PhD students;

- streamlining the rights and responsibilities of PhD students, stimulating independent educational, research and professional activities of PhD students;

- ensuring the recognition of the documents of the Republic of Kazakhstan on awarding the academic degree "Doctor of Philosophy (PhD) in Applied and Engineering Physics" in the labor market in the international educational space.

Mastering the disciplines of the educational program contributes to the formation of the following general universal competencies:

- the ability to plan, develop, implement and adjust a complex research process;
- the ability to critically analyze, evaluate and synthesize new and complex ideas;
- communicate their knowledge and achievements to colleagues, the scientific community and the general public, expanding the boundaries of scientific knowledge;
- to promote the development of a knowledge-based society;
- knowledge and experience for critical analysis, assessment and comparison of various scientific theories and ideas;
- mastery of oratory for public speaking at international scientific forums, conferences and seminars;
- the ability to analyze and process information from various sources;
- demonstration of a systematic understanding of the field of study, the quality and effectiveness of the selected scientific methods;
- participation in scientific events, fundamental scientific domestic and international projects.

Objectives of the educational program:

- training of specialists in the development and implementation of innovative technologies for the production of science-intensive products, in particular, functional materials with desired properties, having qualitatively new consumer characteristics, as well as finished products from them;
- training of scientific and pedagogical personnel for teaching activities in higher and secondary technical educational institutions;
- training of highly qualified specialists for research activities in the field of physics of functional materials.

2 Requirements for applicants

Persons with a Master's degree and work experience of at least 1 (one) year or who have completed residency training are admitted to doctoral studies.

Enrollment in the number of PhD students is carried out by the admissions committees of universities and scientific organizations based on the results of the entrance exam for the groups of doctoral studies and a certificate confirming proficiency in a foreign language in accordance with the common European competences (standards) of proficiency in a foreign language.

When enrolling in universities, PhD students independently choose an educational program from the corresponding group of educational programs.

The enrollment of persons for the targeted training of doctors of philosophy (PhD) under the state educational order is carried out on a competitive basis.

The procedure for admitting citizens to doctoral studies is established in accordance with the "Standard rules for admission to training in educational organizations that implement educational programs of postgraduate education."

The formation of the contingent of PhD students is carried out by placing a state educational order for the training of scientific and pedagogical personnel, as well as paying for education at the expense of citizens' own funds and other sources. The state provides citizens of the Republic of Kazakhstan with the right to receive, on a competitive basis, in accordance with the state educational order, free postgraduate education, if they receive education of this level for the first time.

Upon admission, a PhD student must have all the prerequisites for mastering the relevant professional doctoral study program. The higher education institution determines the list of required prerequisites independently.

In the absence of the prerequisites, the PhD student is allowed to master them on a paid basis. In this case, doctoral studies begin after the PhD student has fully mastered the prerequisites.

3 Requirements for completing studies and obtaining a diploma

Persons who have mastered the educational program of doctoral studies and defended their PhD thesis, with a positive decision of the dissertation councils of the university with a special status or the Committee for Control in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, based on the results of the examination, are awarded the degree of Doctor of Philosophy

(PhD) or Doctor of Science in profile and issued a state diploma with an attachment (transcript).

Persons who have received a PhD degree, to deepen scientific knowledge, solve scientific and applied problems on a specialized topic, carry out a postdoctoral program or conduct research under the guidance of a leading scientist chosen by the university.

3.1 Requirements for key competencies of doctoral graduates:

1) *have an idea:*

- about the main stages of development and the change of paradigms in the evolution of science;
- on the subject, ideological and methodological specifics of the natural (social, humanitarian, economic) sciences;
- about scientific schools of the relevant branch of knowledge, their theoretical and practical developments;
- on the scientific concepts of world and Kazakh science in the relevant field;
- on the mechanism of implementation of scientific developments in practice;
- about the norms of interaction in the scientific community;
- about the pedagogical and scientific ethics of the scientist-researcher;

2) *to know and understand:*

- modern trends, directions and patterns of development of domestic science in the context of globalization and internationalization;
- methodology of scientific knowledge;
- achievements of world and Kazakh science in the relevant field;
- (to understand and accept) the social responsibility of science and education;
- perfect foreign language for scientific communication and international cooperation;

3) *be able to:*

- organize, plan and implement the process of scientific research;
- analyze, evaluate and compare various theoretical concepts in the field of research and draw conclusions;
- analyze and process information from various sources;
- to conduct an independent scientific research, characterized by academic integrity, based on modern theories and methods of analysis;
- generate your own new scientific ideas, communicate your knowledge and ideas to the scientific community, expanding the boundaries of scientific knowledge;
- to choose and effectively use modern research methodology;
- to plan and predict their further professional development;

4) have skills:

- critical analysis, assessment and comparison of various scientific theories and ideas;
- analytical and experimental scientific activities;
- planning and forecasting research results;

- oratory and public speaking at international scientific forums, conferences and seminars;
- scientific writing and scientific communication;
- planning, coordinating and implementing research processes;
- a systematic understanding of the field of study and demonstrate the quality and effectiveness of the selected scientific methods;
- participation in scientific events, fundamental scientific domestic and international projects;
- leadership management and team leadership;
- responsible and creative attitude to scientific and scientific-pedagogical activities;
- conducting patent search and experience in transferring scientific information using modern information and innovative technologies;
- protection of intellectual property rights to scientific discoveries and developments;
- free communication in a foreign language;

5) be competent:

- in the field of scientific and scientific-pedagogical activity in conditions of rapid renewal and growth of information flows;
- in carrying out theoretical and experimental scientific research;
- in the formulation and solution of theoretical and applied problems in scientific research;
- in conducting a professional and comprehensive analysis of problems in the relevant area;
- in matters of interpersonal communication and human resource management;
- in matters of university training of specialists;
- in the examination of scientific projects and research;
- in ensuring constant professional growth.

3.2 Requirements for research and development work of a student under the PhD program:

1) compliance with the main problems of the educational program of doctoral studies, on which the PhD thesis is being defended;

2) is relevant and contains scientific novelty and practical significance;

3) is based on modern theoretical, methodological and technological achievements of science and practice;

4) is based on modern methods of data processing and interpretation using computer technology;

5) is carried out using modern scientific research methods;

6) contains scientific research (methodological, practical) sections on the main protected provisions.

3.3 Requirements for the organization of practices:

The practice is carried out with the aim of developing practical skills in scientific, scientific, pedagogical and professional activities.

The educational program of doctoral studies includes:

1) teaching and research practice - for students under the Ph.D. program;

2) industrial practice - for students under the program of specialized doctoral studies.

During the period of pedagogical practice, PhD students, if necessary, are involved in conducting classes in undergraduate and graduate programs.

The research practice of a PhD student is carried out with the aim of studying the latest theoretical, methodological and technological achievements of domestic and foreign science, as well as consolidating practical skills, applying modern research methods, processing and interpreting experimental data in the dissertation research.

The industrial practice of a PhD student is carried out in order to consolidate the theoretical knowledge gained in the learning process and improve the professional level.

The content of research and industrial practice is determined by the topic of the PhD thesis.

4 Working curriculum of the educational program

MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN
SATBAYEV UNIVERSITY

APPROVED
Rector of Satbayev University
D.K. Baisembetov
2019 г.

CURRICULUM of educational program for 2019-2020 academic year
Applied and Engineering Physics

Mode of study: Full-time Duration: 3 years Academic degree: Doctor of Philosophy (PhD)

Grade level	Code	Name of disciplines	Cycle	Credits ECTS	Credits RK	Classroom volume lec/lab/pr	Prerequisite	Code	Name of disciplines	Cycle	Credits ECTS	Credits RK	Classroom volume lec/lab/pr	Prerequisite
		Term 1							Term 2					
1	PHY305	Synthesis and Physical Properties of Low-dimensional Structures	BD MC	5	3	2/0/1		AAP343	Research work of the doctoral student, including internships and doctoral thesis	AAP	19	5	0/0/5	
	PHY306	Physics and technique of energy saving and renewable energy	BD MC	5	3	1/1/1		AAP304	Pedagogical Practice	AAP	11	11	0/0/11	
	PHY312	Semiconductor heterostructures and devices based on them	SD MC	5	3	2/0/1								
	PHY313	Computer simulation of engineering tasks	SD CC	5	3	1/0/2								
	PHY314	Research Methods for Functional Materials	SD CC	5	3	2/0/1								
	PHY315	Carbon Clusters and Structures	SD CC	5	3	2/0/1								
		Total:		30	18				Total:		30	16		
		Term 3							Term 4					
2	AAP338	Research work of the doctoral student, including internships and doctoral thesis	AAP	18	4	0/0/4		AAP339	Research work of the doctoral student, including internships and doctoral thesis	AAP	30	7	0/0/7	
	AAP306	Research practice	AAP	12	3	0/0/3								
		Total :		30	7				Total :		30	7		
		Term 5							Term 6					
2	AAP339	Research work of the doctoral student, including internships and doctoral thesis	AAP	30	7	0/0/7		AAP338	Research work of the doctoral student, including internships and doctoral thesis	AAP	18	4	0/0/4	
								ECA303	Writing and defending a doctoral thesis	FA	12	4	0/0/4	
		Total :		30	7				Total:		30	8		
									Total:		180	63		

Decision of the Academic Council of Satbayev University. Protocol No 5 from 26 06 2019.

Decision of the Academic Council of the Institute of Industrial Engineering named after A. Burkitbaev. Protocol No 6 of "10" 06 2019

Vice-Rector for Research and Academic Affairs — D.K. Nauryzbaeva
Director of Institute of Industrial engineering — B.O. Omarbekov
Head of "Engineering physics" department — R.E. Beisenov

5 Descriptors of the level and amount of knowledge, abilities, skills and competencies

The third level descriptors within the Comprehensive Qualifications Framework of the European Higher Education Area (EC-EHEA) reflect learning outcomes that characterize the student's abilities:

1) demonstrate a systematic understanding of the field of study, mastering the skills and research methods used in this area (Applied and Engineering Physics);

2) Demonstrate the ability to think, design, implement and adapt an essential research process with a scientific approach;

3) contribute with their own original research to expand the boundaries of the scientific field, which deserves publication at the national or international level;

4) critically analyze, evaluate and synthesize new and complex ideas;

5) communicate their knowledge and achievements to colleagues, the scientific community and the public;

6) to promote, in an academic and professional context, the technological, social or cultural development of a knowledge-based society.

6 Annex to the diploma for standard ECTS

The application was developed according to the standards of the European Commission, Council of Europe and UNESCO / CEPES. This document is for academic recognition only and is not an official proof of education. Not valid without a university degree. The purpose of completing the European Supplement is to provide sufficient information about the holder of the diploma, the qualification obtained, the level of this qualification, the content of the study program, the results, the functional purpose of the qualification, as well as information about the national education system. The application model that will be used to translate grades uses the European Credit Transfer or Transfer System (ECTS).

The European Diploma Supplement provides an opportunity to continue education at foreign universities, as well as to confirm national higher education for foreign employers. When going abroad for professional recognition, additional legalization of the educational diploma is required. The European Diploma Supplement is filled in English upon individual request and is issued free of charge.

Physical Properties of Low-dimensional Structures
THE CODE -
CREDITS - 5 credits
PREREQUISITES: PHY149 Quantum Mechanics, PHY196 Condensed Matter Physics, Fundamental Foundations of Modern Technologies, Physicochemical Basis for the Production of Functional Materials and Structures.
PREREQUISITES - Master's degree.

PURPOSE OF STUDY: To form among PhD students a modern scientific understanding of the physical properties of electronic systems of various dimensions, how the decrease in dimension affects physical phenomena, and what new effects appear in this case.

OBJECTIVES OF THE COURSE "Physical Properties of Low-dimensional Structures" are to acquaint PhD students with the fundamental concepts of solid state physics for systems with a reduced dimension, to instill in them the basics of understanding the physical processes occurring in these systems under external influences, and also to give an idea of the use of these phenomena in modern fields of technology at the level of modern advanced knowledge accumulated at the moment by the world scientific community with the use of generally accepted international vocabulary and terminology.

SUMMARY:
Dimensional quantization of electron energy. Conditions for observing quantum-size effects. Low-dimensional electron gas structures. Technology for obtaining quantum-dimensional structures. Molecular Beam Epitaxy. Gas-phase epitaxy from metal-organic compounds. Lithography. Self-organization of quantum dots and threads. Charge carriers in low-dimensional structures. Density of states in electronic systems with reduced dimension. Media statistics in low-dimensional structures. Transition from discrete to continuous spectrum in the direction of quantization for systems of various dimensions. Quasi-low-dimensional systems. Shielding 2D, 3D case. Hydrogen-like atom, exciton in 3D, 2D, 1D cases. Optical properties of quantum wells. Interband absorption. Interlevel transitions. Optical ionization of quantum wells. Depolarization effects. Kinetic effects in two-dimensional systems. Relaxation time and mobility. Scattering mechanisms. Integer quantum Hall effect. Fractional quantum Hall effect. Quantum interference corrections to conductivity. Properties of quantum threads and dots. Ballistic transport. Ballistic conductivity of filaments. Relationship between QHE and quantization of conductance in filaments. Coulomb blockade. Tunnel effects Double-barrier structures. Transmission coefficient, reflection. Quasi-stationary states of an electron in a well. Energy dependence of the resonant transmission coefficient. Influence of the magnetic field on tunneling. Application of quantum-dimensional structures in micro- and nanoelectronic devices. Lasers with quantum wells and dots. Optical modulators. Photodetectors based on

quantum wells. Transistors with high carrier mobility. Devices based on ballistic transport. Devices based on a single-electron transistor.

Physics and technology of energy conservation and renewable energy
CODE - PHY306
CREDITS - 5 credits
PREREQUISITES - Physics I, Physics II, Physics III

PURPOSE OF STUDY: the formation of PhD students' knowledge and skills in the field of prospects for the use of alternative energy sources, which will stimulate their activities for the development of this area of technology and technology.

SUMMARY: The discipline is devoted to the description and analysis of renewable energy sources, their use in the general energy balance of the country and regions. The discipline also covers issues of global energy conservation in industry, agriculture and housing and communal services. The issues of using secondary energy resources and improving environmental conditions are also considered; technical and economic indicators of the use of renewable energy sources in agriculture; application of resource-saving technologies using renewable energy sources. Self-training of PhD students includes mastering lecture material using recommended literature, independent study of individual issues (designs and electrical circuits of certain types of equipment, issues of using technology in various fields, etc.), performing computational work.

KNOWLEDGE, ABILITY, COURSE COMPLETION SKILLS: Ability to participate in planning research in the field of using alternative energy sources. As a result of mastering the discipline, the student must: know: - the main traditional and non-traditional renewable energy sources; principles and methods of practical use of renewable energy sources; be able to: - calculate thermal schemes of facilities with renewable energy sources; own: - the skills of analyzing information on the technical parameters of power plants using renewable energy sources; - terminology in the field of alternative energy; - Problems of the use of renewable energy sources.

Research methods for functional materials
THE CODE - PHY314
CREDITS - 5 credits
PREREQUISITES - Spectral methods for studying low-dimensional objects, Practical aspects of X-ray diffractometry

PURPOSE OF STUDY: to form the PhD students' ideas about the methods of transmission electron and probe microscopy for diagnosing the structure and properties of low-dimensional materials and to teach how to operate modern equipment used for these purposes.

SUMMARY:
The main objectives of the course are to provide PhD students with basic information about transmission electron and probe atomic force microscopy: the device and basic characteristics of devices, the theory of formation and interpretation of the images obtained, to form theoretical and practical skills in working with transmission electron and probe atomic force microscopes. Electron and scanning probe microscopy are one of the main methods for analyzing and modifying the surface of a sample and a substrate, which are widely used in the field of modern technologies when conducting scientific research of the physical and chemical properties of objects with high spatial resolution.

KNOWLEDGE, ABILITY, SKILLS ON COMPLETION OF THE COURSE: skills and abilities of conducting experimental research using electron and probe microscopy methods and processing the results will be formed.

Computer simulation of engineering tasks
THE CODE - PHY313
CREDITS - 6 credits
PREREQUISITES - Physics I, Physics II, Physics III, Methods of theoretical physics, Numerical methods for solving physical problems

PURPOSE OF STUDY: to teach the construction of mathematical models of various physical phenomena, to study the basic methods of solving the mathematical problems arising in this case, to clarify the physical meaning of the solutions obtained.

SUMMARY: Building a mathematical model (drawing up equations describing the phenomenon under study). Selection of numerical calculation methods (construction of a discrete model that approximates the original mathematical problem, construction of a

difference scheme, development of a computational algorithm, etc.). Creation of a program that implements a computational algorithm. Calculations and processing of the information received. Analysis of the results of calculations, comparison (if possible) with a field experiment. The discipline "Computer modeling of engineering problems" connects the analysis of physical processes with the tools of modern information technologies, and therefore plays an integrating role, contributing to the development of skills in using computing systems to solve professional problems.

KNOWLEDGE, ABILITIES, SKILLS FOR COMPLETION OF THE COURSE: As a result of mastering the discipline, the PhD student: 1. should know: about the main classifications of mathematical models, about the principles of modeling, about the main stages, technologies for building a model, about the possibilities of software implementations using tools, about the features of conducting computational experiments. 2. must be able to: independently select a method for solving and constructing an algorithm for a particular engineering problem, give a complete analysis of the solution results and evaluate the limits of applicability of the selected model. 3. must possess: knowledge of modeling as a method of cognition; methods of using spreadsheets, specialized mathematical packages (MATCAD, MATLAB), integrated programming environments for building computer models necessary for solving engineering problems; the main methods of analyzing the modeling process and modeling results; the main methods for assessing the quality of the model used, including when solving problems related to professional activities; the skills of solving applied problems using visual modeling environments to formalize the description of the system under study, the necessary mathematical transformations of its model, as well as to effectively solve practical problems of modeling processes and phenomena, and analyze the characteristics of the systems being designed.

Carbon clusters and structures

THE CODE - PHY315

CREDITS - 5 credits

PREREQUISITES - PHY196 Condensed Matter Physics, Fundamentals of Modern Technologies, Physicochemical Basis for the Production of Functional Materials and Low-Dimensional Structures.

PURPOSE OF STUDY: To reveal the essence of the basic concepts of systems with limited dimension, synthesis of carbon clusters and structures, methods of their research and application.

SUMMARY: The discipline "Carbon Clusters and Structures" covers the field of physical, chemical and interdisciplinary knowledge required by the modern engineer. Includes sections: systems with limited dimension, particle synthesis, research methods for functional materials, nanoelectronics, composites and organic semiconductors. This discipline includes the following: assembly of fullerenes from graphite fragments, the "snail" model, assembly from clusters, annealing of carbon clusters. Selection of magic fullerenes and fullerene isomers. The mechanisms of the formation of carbon particles, as well as their relationship with the mechanisms of the formation of fullerenes are given. Modeling possible mechanisms for the formation of carbon particles using molecular dynamics. Possible nuclei for growth and growth mechanisms of single-shell and multi-shell nanotubes, as well as carbon cones. Low-dimensional carbon-containing objects creating methods.

KNOWLEDGE, ABILITIES, SKILLS FOR COMPLETION OF THE COURSE: skills and abilities will be formed to solve theoretical and experimental - practical problems to create carbon clusters and structures based on them.

Semiconductor heterostructures and devices based on them
THE CODE - PHY312
CREDITS - 5 credits
PREREQUISITES - Physics of low-dimensional systems. PHY149 Quantum Mechanics, PHY196 Condensed Matter Physics, Fundamentals of Nanotechnology.

PURPOSE OF STUDY: to form among PhD students a modern scientific understanding of the types and properties of double heterostructures, methods of their preparation and methods of application in electronics.

SUMMARY: the discipline "Semiconductor heterostructures and devices based on them" is a profiling discipline in preparation for the research activities of PhD PhD students in the specialty "Applied and Engineering Physics". The discipline "Semiconductor heterostructures and devices based on them" gives an idea of the types of solid-state heterostructures, the technology of their manufacture and the use of heterostructures in nanoelectronic and optoelectronic devices.

KNOWLEDGE, ABILITY, SKILLS TO COMPLETE THE COURSE: skills and abilities to solve theoretical and experimental - practical problems related to the consideration of heterostructures with quantum wires and dots. For PhD students, the essence of the processes of formation of solid-state heterostructures and their physical properties will be revealed.

High energy physics
THE CODE -
CREDITS - 5 credits
PREREQUISITES - Nuclear Physics and Physics of Elementary Particles

PURPOSE OF STUDY: Mastering by PhD students the approaches and methods used in modern experiments and comparing the results of experiments and predictions of theories. Acquaintance with the main results that lay the foundation for the experimental verification of the Standard Model.

SUMMARY: The lecture course contains a discussion of the foundations, methods, directions and the current state of experimental high-energy physics. Measurements that are critical for testing the principles and refining the parameters of the standard theory and seeking a possible way out of it are discussed in detail. Experiments carried out at the LEP and SLC colliders, as well as experiments at the LHC and planned at the ILC, are discussed in detail. Particular attention is paid to the problems and prospects of neutrino physics, in particular, experiments on measuring masses and mixing, in which manifestations of new physics are possible.

KNOWLEDGE, ABILITY, SKILLS ON COMPLETION OF THE COURSE: Because of mastering the discipline, knowledge of the fundamentals and modern trends in the development of high-energy physics and the ability to critically assess the prospects of various areas of research and experiments to achieve certain goals are acquired.

Processes for obtaining functional materials
THE CODE -
CREDITS - 5
PREREQUISITES - PHY196 Condensed Matter Physics, Fundamentals of Nanotechnology

PURPOSE OF STUDY: to reveal the essence of synthesis processes of low-dimensional objects and structures processes occurring on the surface and in near-surface layers.

SUMMARY: the discipline "Processes of obtaining functional materials" gives an idea of the synthesis and analysis of the morphology, structure, chemical and phase composition of functional materials, allows you to acquire knowledge about chemical, physical and biological methods of synthesis of low-dimensional structures and materials, about methods of controlled growth to obtain low-dimensional structures of the required

size and shape, methods of synthesis of films and coatings, massive structured and microporous materials, stabilization of particle dispersions and self-organization of low-dimensional structures in films and bulk structures.

KNOWLEDGE, SKILLS, AT THE COMPLETION OF THE COURSE: to form the skills and abilities of solving theoretical and experimental - practical problems, to analyze the advantages and disadvantages of various methods of synthesis of particles and functional materials, to choose rational methods for the synthesis of low-dimensional objects and functional materials.

PhD student research work, including internships and PhD thesis

THE CODE - AAP345

CREDITS - 115 credits

The PURPOSE of the research work of the PhD student, including the internship and the implementation of the PhD thesis, is: development of the ability to independently carry out research work related to solving complex professional problems on the topic of dissertation work.

SHORT DESCRIPTION: The tasks of the R&D work are: ensuring the formation of professional scientific research thinking of PhD students, forming in them a clear idea of the main professional tasks, ways of solving them; formation of skills to use modern technologies for collecting information, processing and interpreting obtained experimental and empirical data, possession of modern research methods; ensuring readiness for professional self-improvement, the development of innovative thinking and creative potential, professional skills; carrying out bibliographic work using modern information technologies.

Pedagogical practice

THE CODE - AAP350

CREDITS - 11 credits

THE PURPOSE of pedagogical practice is: to study the foundations of pedagogical and educational-methodical work in higher educational institutions, to master pedagogical skills in conducting certain types of training sessions in the disciplines of the profile corresponding to the direction of study.

BRIEF DESCRIPTION: Pedagogical practice is a type of practical activity of PhD students, which includes teaching general and major disciplines, organizing students'

educational activities, scientific and methodological work in the subject, obtaining skills and abilities in the work of a teacher. The organizer of the teaching practice is the base department, in the corresponding direction of the educational program. The head of the teaching practice of the PhD student is the scientific supervisor.

Research scientific training

THE CODE - AAP349

CREDITS - 12 credits

The PURPOSE of research practice is:deepening and consolidating PhD students' knowledge, skills and abilities acquired in the course of mastering the disciplines of professional training by focusing on the main areas of scientific research corresponding to the topic of the dissertation work.

BRIEF DESCRIPTION: Research practice refers to industrial practices and is a practice to obtain professional skills and professional experience.

Writing and PhD thesis defending

THE CODE - ECA303

CREDITS - 12 credits

The PURPOSE of performing a PhD thesis is to assess the scientific-theoretical and research-analytical level of a PhD student, formed professional and managerial competencies, readiness for independent performance of professional tasks and compliance of its preparation with the requirements of the professional standard and the educational program of doctoral studies.

SHORT DESCRIPTION

PhD thesis is a scientific work of a PhD student, which is an independent study, in which theoretical provisions are developed, the totality of which can be qualified as a new scientific achievement, or a scientific problem is solved, or scientifically grounded technical, economic or technological solutions are set forth, the implementation of which makes a significant contribution to development the country's economy.

The PhD thesis is the result of the research / experimental research work of the PhD student, carried out during the entire period of the PhD student's training.

The defense of a PhD thesis is the final stage in the preparation of a doctoral candidate. A PhD thesis must meet the following requirements:

- the topic of the thesis should be related to the priority areas of development of science and / or government programs or programs of fundamental or applied research;
- the content of the thesis, the goals and objectives, the scientific results obtained must strictly correspond to the topic of the thesis;

- the dissertation is carried out in compliance with the principles of independence, internal unity, scientific novelty, reliability and practical value.

Content