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Development of conformed and compatible/unified curricula

Report

Deliverable No 2.2

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Contents

Records of changes

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Introduction

1. The purpose of the Report

The report on Development of conformed and compatible/unified curricula is a description of a progress on development of study programs in partner universities. The project involves higher education institutions from such partners: BSU - Belarusian State University, GrSU, Grodno State University, GoSU, Gomel State University, BSTU, Belarusian State Technological University, which have to provide data for this report.

Partners submit the reports with attachments of education curricula description copies.

According to the Log-Frame Matrix the consortium has to provide outputs and to submit evidences related project achievements:

2.1. The number of teaching materials developed: lecture notes/synopsises, descriptions/manuals of laboratory works, courses books, etc.

2.2. The number and names of Standard master-level programs with ECTS system' application, *accredited in the Ministry of Education*.

2.2.1. The number and names of education courses with ECTS system' application, *accredited in the partner's university*.

2.4. The number of study programs for master-level courses descriptions

3.2. The number of teaching/didactic materials uploaded to e-Library

3.3. Virtual laboratory for student training, the instruction for its on-line usage

2. Summary

2.1 The number and titles of Standard master-level programs with ECTS system' application, accredited in the Ministry of Education.

List of curricula validated by Ministry of Education RB:

1. 1-31_81_02-Photonics for 4-5-year courses 2012
2. 1-31_81_03-Functional nanomaterials for 4-5-year courses 2012
3. Curricula_81 02 Photonics_2 year master level 2017
4. Curricula _81 03 Functional nanomaterials_2 year master level 2017

These curricula are presented in the Moodle platform of BSU by the Internet-address https://dl.bsu.by/mod/folder/view.php?id=27007

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GrSU, Grodno State University 1 Standart **_1-31_81_04-2012-1_copy.pdf** in attachment.

List of curricula validated by Ministry of Education RB:

1. 1-31 80 05 - Physics 1 year
2. 1-31 80 05 - Physics 2 year

These curricula are presented in the Moodle platform of BSU by the Internet-address https://dl.bsu.by/mod/folder/view.php?id=27007..

2.2 The number and titles of education courses with ECTS system' application, accredited in the partner's university.

BSU - Belarusian State University

List of courses study programs validated by BSU vice-rector:

No	Course/Lab title	Level (Bachelor, Master 5-year course)	ECTS credit points	Preli-minary number of students	Type of delivery (lecture, lab, practical)	Duration of the course (since …. to)	Type of control (set-off, exam)	Background subjects/ preliminary knowledge
	Composite nanostructured	5-year course	2,0	5	Lecture	01.09.17	exam	Molecular Physics, Electricity, Quan-

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	materials					– 25.01.18		tum Mechanics, Fundamentals of material science
	Nanomaterials in energetics	5-year course	2,0	5	Lecture	01.09.17 – 25.01.18	Set-off	Molecular Physics, Electricity, Quan-um Mechanics, Thermodynamics, Fundamen-tals of material science
	Physics and Chemistry of Surface	Bachelor	2,5	4	Lecture	01.09.17 – 25.01.18	exam	Molecular Physics, Electricity, Quan-tum Mechanics, Thermo-dynamics, Fundamentals of material science
	Optics of nanostructures	Bachelor	2	5	Lecture	01.09.17 – 25.01.18	Set-off	Molecular Physics, Optics, Quantum Mechanics, Funda-mentals of material science
	Thermodynamics of nanosystems	Bachelor	2	4	Lecture	10.02.18-25.06.18	Set-off	Molecular Physics, Quantum Mecha-nics, Thermodyna-mics, Fundamentals of material science
	Opto- and microelectronics	Bachelor	2	4	Lecture	10.02.18-25.06.18	exam	Electricity, Quan-tum Mechanics, Fundamentals of material science
	Physics of electri-cally conductive polimers	5-year course	2	5	Lecture	01.09.17 – 25.01.18	set-off	Molecular Physics, Electricity, Quan-tum Mechanics, Fundamentals of material science
	Nanotechnologies in electronics	5-year course	2	5	Lecture	10.02.18-25.06.18	exam	Molecular Physics, Electricity, Quan-tum Mechanics, Fundamentals of material science
	Spintronics	5-year course	2	5	Lecture	01.09.17 –	set-off	Molecular Physics,

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						25.01.18		Electricity, Quan-tum Mechanics, Fundamentals of material science
	Physics and Chemistry of Surface	5-year course	2,5	5	Lecture	10.02.18-25.06.18	exam	Molecular Physics, Electricity, Quan-tum Mechanics, Thermo-dynamics, Fundamentals of material science
	Laser Physics	Bachelor	2,5	4	Lecture	01.09.17 – 25.01.18	exam	Optics, Quantum Mechanics, Non-linear Optics, Fiber Optics, Coherent Optics and Holography

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GrSU, Grodno State University

No	Course/Lab title	Level (Bachelor, Master 5-year course)	ECTS credit points	Preli-minary number of students	Type of delivery (lecture, lab, practical)	Duration of the course (since …. to)	Type of control (set-off, exam)	Background subjects/ preliminary knowledge
	Nanophotonics	master	4	8	Lecture, lab	01.09.17 – 30.12.17	exam	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics, statistical physics, electrodynamics, electric engineering, electronic devices

GoSU, Gomel State University

List of courses study programs validated by GoSU vice-rector:

No	Course/Lab title	Level (Bachelor, Master 5-year course)	ECTS credit points	Preli-minary number of students	Type of delivery (lecture, lab, practical)	Duration of the course (since …. to)	Type of control (set-off, exam)	Background subjects/ preliminary knowledge
	Sol-gel synthesis of	2-year master	4	10	Lecture,	09.02.19	exam	Molecular Physics,

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	functional materials				lab	– 12.04.19		Electricity, Quantum Mechanics, Thermo-dynamics, Fundamentals of material science
	Physics of wave processes	2-year master	4	10	Lecture, practical	09.02.18 – 12.04.18	exam	Molecular Physics, Electricity, Quantum Mechanics, Thermo-dynamics, Fundamentals of material science
	Modulators of a laser radiation	2-year master	4	10	Lecture, lab	09.02.19 – 12.04.19	exam	Molecular Physics, Electricity, Quantum Mechanics, Thermo-dynamics, Fundamentals of material science
	Industrial lasers	2-year master	4	10	Lecture, lab	09.02.19 – 12.04.19	exam	Molecular Physics, Electricity, Quantum Mechanics, Thermo-dynamics, Fundamentals of material science
	Metamaterials	2-year master	4	10	Lecture, lab	09.02.19 – 12.04.19	exam	Fundamentals of general physics and mathematics, Quantum mechanics, Statistical Physics, Optics, Electricity
	Ellipsometry	2-year master	4	10	Lecture, lab	09.02.19 – 12.04.19	exam	Fundamentals of general physics and mathematics, Quantum mechanics, Statistical Physics, Optics, Electricity
	The modern ideas of matter structure	1-year/ 2-year master	3	27	Lecture	01.09.17 – 25.01.18	exam	Optics of light bunches, Computer model operation, Optics, Quantum mechanics
	Computer simulation	1-year/ 2-year master	3	27	Lecture, practical	01.09.17 – 25.01.18	exam	Fundamentals of general physics and mathematics, IT
	Quantum theory of atomic and molecular	2-year master	4	10	Lecture, practical	01.09.17 –	exam	Molecular Physics, Electricity,

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	spectra					25.01.18		Quantum Mechanics, Thermo-dynamics, Fundamentals of material science

List of courses study programs validated by BSTU vice-rector:

No	Course/Lab title	Level (Bachelor, Master 5-year course)	ECTS credit points	Preli-minary number of students	Type of delivery (lecture, lab, practical)	Duration of the course (since …. to)	Type of control (set-off, exam)	Background subjects/ preliminary knowledge
	Functional Nanomaterials	Master	1,0	4	Lecture	01.09.17 – 25.01.18	Set-off	Chemistry and physics of polymers, Theoretical basis for processing polymers and composites, courses of special disciplines
2.	Promising technologies for processing polymers and composites	Master	3,0	4	Lecture	01.09.17 – 25.01.18	Exam	
3.	Theoretical basis of polymer processing	Master	4,0	4	Lecture	10.02.18 – 25.06.18	Exam	Chemistry and physics of polymers, Theoretical basis for processing polymers and composites, courses of special disciplines
4.	Modification of polymers and composites	Master	1,0	4	Lecture	01.09.17 – 25.01.18	Set-off	

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3. Belarusian State University Information

To improve education in Physics, Applied Physics, Nanomaterials, Nanotechnologies and Photonics in Belarusian universities and to make it closer to Bologna system, BSU has developed new Curricula for 2-year masterships by specialties 1-31 81 03 Functional materials and 1-31 81 02 Photonics and also renewed training programs for 5-year study and 1-year masterships for the previous 5+1 system 1-year masterships. The description of new Curricula was presented in the previous Activity Reports 1 and 2. These Curricula are divided on 3 parts (components): Preliminary State (mandatory) component, University component and Courses at students` option. Every Curricula includes titles of courses, values of hours and some other information (number of lectures, type of reporting, etc.). Validated versions of Curricula in Russian and English, study programs of the developed courses and didactic materials to them (synopsises, presentations, etc.) are presented in Appendixes 1 and 2.

3.1. Description of the courses / education programs

Course "Composite nanostructured materials"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Composite nanostructured materials
Course status in the programme	Compulsory
Course level	Undergraduate Studies, Master studies
Course type	Academic
Field of study	Specialty “Functional Nanomaterials” and “Physics of nanomaterials and nanotecnologies”

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Responsible instructor	Alexander Fedotov
Academic staff	Nikolay Gorbachuk
Volume of the course: parts and hours	30 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	This course is devoted to familiarization of students with electrical properties of nanostructured compositions of metals, semiconductors and dielectrics, as well as modern practical problems solved within the framework of this section of materials science.
Goals and objectives of the course in terms of competences and skills	To demonstrate to undergraduate students of 5th course and 2-year master-students the fundamentals of carrier charge transport in electrically conductive composite materials; to promote the formation of students' ideas about the relationship between the phenomena of carrier transport and the structure of composites; to familiarize students with the basic theories and models of electron transport in nanogranular composites; to teach students to understand the possibilities of practical use of the acquired knowledge in solving specific problems
Structure and tasks of independent studies	At home must be prepared 14 tests from 7 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	N.I. Gorbachuk, A.K. Fedotov. Chapter 8. Electrically conductive nanocomposites. In e-Book "Functional nanomaterials" http://dl.bsu.by/course/view.php?id=849; http://dl.bsu.by/pluginfile.php/98607/mod_resource/content/1/Chapter%208.%20Electrically%20conductive%20nanocomposites%20RUS%20-%2028.04.2017.pdf
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, electrodynamics, electric engineering, solid state physics, phase transformations in solids, physics and chemistry of surface.
Courses acquired before	Basics of solid-state physics and material sciences

Course outline

Theme	Hours
Lectures	
1. Statement of the problem and basic definitions. *Definition of basic concepts*. The concept of a binder (matrix) and filler (dispersed phase). Conducting cluster. Technologies for obtaining composite materials. Metal-insulator composites. Polymer composites. Ceramics. Methods for the preparation of granular metal-dielectric composites.	2
Effect of matrix and filler interaction on the conductivity of composites. *Methods for describing the electrical conductivity and dielectric constant of heterogeneous systems.*	2
2. General provisions of percolation theory *General provisions of the theory of percolation*. Introduction. Tasks of nodes and connections. Infinite cluster. *The probability of percolation*. Statement of the problem of nodes on a square grid. The probability of percolation. Percolation threshold. The notion of the percolation threshold (critical probability). Length (radius) of the correlation. Critical indices. The percolation thresholds for the tasks of nodes and connections for various types of lattices.	2
Models for describing the structure of a percolation cluster. The correlation radius. Model Skal-Shklovsky-de wife. A drop model of a randomly inhomogeneous heterogeneous system	2
3. Application of the theory of percolation to describe the electrical conductivity of heterogeneous systems	2

Effective DC conductivity. Conductivity beyond the threshold of percolation. Conductivity near the percolation threshold. Critical indices. *Dielectric permeability of composites*. Behavior of the permittivity near the percolation threshold. Critical index.	
4. Electroconductive composite materials. *Binary heterogeneous systems*. Equivalent schemes of composite materials with micron-sized filler. Resistor-capacitive model. *Metal-insulator transition*. The weak link model.	2
5. Influence of the interlayers of the dielectric matrix in a conducting cluster on the impedance of composites. *Equivalent schemes of metal-insulator composites*. Construction of impedance hodographs. *Frequency dependences of impedance*. The real parts before and beyond the threshold of percolation. Reactive part of the impedance before and behind the percolation threshold. The effect of negative capacitance.	2
6. Model of an effective medium for describing the dielectric properties of nonconductive (porous) composite materials. *Theory of effective medium*. Formulation of the problem. *Influence of the morphology of the medium on the properties of composites*. Symmetrical model for mixtures with two continuous phases. Bruggeman's formula. Asymmetric approach for matrix-filler mixtures. The Maxwell-Garnett equation. The Lüyengi equation. Lichtenecher's equation. Equation of Brown.	2
7. Peculiarities of electrical conductivity of nanogranular metal-insulator composites. *Electrical properties of granular metal-dielectric composites*. Levels of consideration of electrotransport in granular nanocomposites. Factors affecting the position of the percolation threshold in metal-insulator nanocomposites. *Temperature dependences of the conductivity of granular nanocomposites*. Nonmetallic mode of electrotransport. Metallic mode of electrotransport. Influence of the structure of metallic nanoparticles on the electrotransfer regimes.	2
Hopping mechanisms of electrical conductivity of nanocomposites. The Mott model. The Shklovsky-Efros model. Density of states. *Models of electron tunneling*. Model of Thermally Activated Tunneling of Sheng-Eibles. Model of inelastic resonance tunneling. *I-V characteristics of nanogranular composites*. The Coulomb blockade. Activation of electrons above the Coulomb barrier.	2
The influence of the measurement modes on the temperature dependences of the electrical resistivity of nanogranular composites. Measurement of electrical resistance in the regime of direct current. Measurement of electrical resistance in the regime of constant voltage.	2
Impedance of inductive type in metal-insulator nanocomposites. The effect of negative capacitance. The effect of the structure of metallic nanoparticles is the effect of negative capacitance. Model of hopping conductivity on an alternating current with a frequency-dependent exponent in the Mott law	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know methods of manufacturing electrically conductive composite materials; physical foundations of the percolation theory; methods of applying the percolation theory to describe the electrical conductivity of heterogeneous systems; the relationship between the structure composite materials and their electrical properties; mechanisms of electrical conductivity of metal-insulator composites; basic theories and models of electrical properties of composite materials with micron-sized matrix particles and fillers; specific features of carrier transport in nanogranular metal-insulator composites; practical applications of electrically conductive composite materials.	Ability to solve corresponding problems
Be able to apply theoretical models to describe the electrical conductivity of heterogeneous systems; conduct experiments to study the electrical properties of composite materials on direct and alternating current; analyze the mechanisms of electrical conductivity of metal-dielectric composites; solve problems in the field of practical applications of electrically conductive composite materials.	Ability to solve corresponding problems
To possess methods of impedance spectroscopy for the study of electro transfer in composite materials; methods for measuring the electrical conductivity of composite materials at a constant	Ability to solve corresponding problems

current; the methods of practical use of the knowledge gained when solving specific problems within the framework of studies of electro transfer processes in composite materials.	
To be able to execute 7 written tests by 14 lectures (consisting of 5 questions every)	To give the right answers on 4 of 5 questions

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	24	-	-	-	+	-	+	6

Course "Physics and Chemistry of Surface"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Physics and Chemistry of Surface
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Functional Nanomaterials”
Responsible instructor	Alexander K. Fedotov
Academic staff	Alexander Mazanik Alexander S. Fedotov
Volume of the course: parts and hours	1 part, 42 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	This course describes atomic and electronic structure of surfaces/interfaces; thermodynamics of surfaces/interfaces; physical/chemical processes at real surfaces/interfaces; influence of surfaces/interfaces on the formation of properties of solid materials and multilayered devices; methods of clean surfaces preparation; methods for surfaces/interfaces characterization.
Goals and objectives of the course in terms of competences and skills	To demonstrate to master-students the fundamental ideas and physical/chemical principles of description and forming clean surfaces/interfaces in crystalline solids; to give knowledge of their atomic and electronic structure; to learn the main physical/chemical processes that determine real structure of surfaces/interfaces in crystalline solids and electronic devices on their base; to describe a role of surfaces/interfaces in the formation of properties of functional nanomaterials and low-dimensional solid-state devices; to get main competences and skills in the preparation and experimental study of surfaces/interfaces in functional nanomaterials and devices on their base.
Structure and tasks of independent studies	At home must be prepared 15 tests and written 1 essay from 8 main parts of the course within the framework of Controlled Independent Work (CIW) of students

Recommended literature	A.K. Fedotov. Introduction to Physics and Chemistry of surface. http://dl.bsu.by/pluginfile.php/76007/mod_resource/content/1/IntrToChemPhysSurfErasmusRu.pdf
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics, statistical physics, electrodynamics, electric engineering, electronic devices
Courses acquired before	Basics of material sciences and solid-state devices

Course outline

Theme	Hours
Lectures	
1. Introduction to the subject. The external and internal surfaces in solids. Ideal and non-ideal surfaces in solids. The role of the surface in a variety of physical and chemical processes. The phenomena of wetting and spreading. Inhomogeneous surfaces: physical, chemical and induced inhomogeneities. A role of external and internal surfaces in the physics and chemistry of nanosystems.	2
2. Atomically clean surfaces. Thermodynamics of atomically clean surfaces. Surface tension and surface stresses. The anisotropy of the surface tension. Surface melting.	2
The ideal crystal surface. The surface in the macroscopic and microscopic sense. Atomic structure of the ideal crystal surface. The nature of chemical bonds at the surface of solids. Relaxed and reconstructed surfaces. The symmetry properties of the relaxed and reconstructed surfaces. Crystallographic methods to describe the relaxed and reconstructed surfaces. Structural defects at the atomically clean surfaces. Experimental data on the atomic structure of the surface in semiconducting and metallic materials.	2
3. Dynamics of atoms at atomically clean crystalline surfaces The vibrations of atoms near the surface. Analysis of the vibrational spectrum of the atoms in the atomically-clean surface. Experimental data on the vibrations of surface atoms. The thermal expansion of the surface lattices. Effect of atomic vibrations at the surface on the properties of solids.	2
4. Band model of the atomically clean surfaces in crystals. The electronic structure of the surface in solids. "Jelly" model. The one-dimensional band theory. Three-dimensional band theory. Electron emission and surface ionization. Electronic structure of semiconductor surfaces. Surface levels and band bending in semiconductors. A phenomenological description of the surface in semiconductors. Zone diagramms. The main characteristics of the space charge region (SCR) in thermodynamically equilibrium and non-equilibrium conditions. SCR charge. An excess of free charge carriers in the SCR.	2
Tamm and Shockley surface states in semiconductors. Fluctuations in the surface potential. Admittance of surface states. Electrophysical characteristics of the SCR at the surface. Surface photo-emf. Electrophysical dimensional effects in SCR. Processes of eelectron transfer in SCR. The effective electron mobility in the SCR. The main mechanisms of influence of surface on electron phenomena in semiconductors. Electron transfer processes in thin films. Influence of surface scattering on charge carriers transport phenomena. The diffuse and specular scattering. Surface scattering mechanisms.	2
5. The actual surface. Physical adsorption. The thermodynamic approach. The forces acting upon adsorption. The simplest of the adsorption isotherms. Langmuir adsorption isotherm. Isoterm polymolecular adsorption. Adsorption from the liquid phase. The changes in the properties of solids due to adsorption. A role of adsorbed atoms in the formation of surface structures. Electronic structure of surfaces with adsorbates. Vibrations of adsorbed atoms. Experimental methods for the study of adsorption.	2
Chemisorption on metals and semiconductors. The structure of the surface at the crystal due to chemisorption. Phase transitions. The impact of external influences on phase transitions at the surface. The electronic structure of the surface in metals and	2

semiconductors due to chemisorption. Schottky barrier and band shifts.	
Surface diffusion. The reactions at the surfaces. The influence of external impacts on the surface phase transitions.	2
6. The internal boundaries (interface). The atomic structure of interfaces: the grain boundaries in polycrystals and bicrystals, interphase boundaries. Electronic structure of interfaces in the structures metal-semiconductor, metal-insulator, semiconductor-dielectric, superlattices and others. Transport of charge carriers in the vicinity of the interface. Energy diagrams of Schottky barriers and MIS structures. The electrical neutrality equation. The capacity and the current-voltage characteristics. The potential fluctuations. Admittance of the states at the interface.	2
7. Methods for the preparation of atomically-clean surfaces. Experimental methods for the creation of clean surfaces. Methods for preliminary surface cleaning. Methods with vacuum cleaning: thermal desorption,, ion etching, catalytic reactions, sputtering, cleavage.	2
8. Methods of studying the structure of the surface and interface. Methods of studying the chemical composition, atomic structure and atomic dynamics at the surface. Auger electron spectroscopy. X-ray photoelectron spectroscopy. Mass spectroscopy of secondary ions. Rutherford back-scattering. IR spectroscopy. Raman spectroscopy. Thermic-stimulated desorption. Ellipsometry. Electron microscopy. Difraction of slow electrons. Scanning tunneling microscopy. Atomic force microscopy. Electronic spectroscopy of characteristic losses.	2
Electrophysical methods for the study of surface states in semiconductors. Measurement of surface conductivity. Electroreflection. The field effect. Measurement of surface photo-emf. Measurement of the double layer capacitance. The work function measurement: a diode, a capacitor, photoemission. Field methods.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To understand the basic ideas and approaches to manufacturing and characterization of atomically-clean surfaces	Ability to solve corresponding problems
To understand main physical and chemical processes, proceeding at real surfaces/interfaces and controlling their properties	Ability to solve corresponding problems
To understand the mechanisms of surface/interface influences on functional properties of nanomaterials and device structures	Ability to solve corresponding problems
To be able to execute 15 short tests by 15 lectures (consisting of 5 questions every)	To give the right answers on 4 of 5 questions
To be able to execute 3 written tests (consisting of 3 questions every)	To give the right answers on 2 of 3 questions
At home must be done 1 essay	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	34	-	-	+	+	+	+	8

Course "Nanomaterials in energetics"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Nanomaterials in energetics
Course status in the programme	Obligatory
Course level	Graduate level
Course type	Academic
Field of study	Specialty “Functional nanomaterials”
Responsible instructor	Andrei Larkin
Academic staff	Andrei Larkin Alexander Mazanik
Volume of the course: parts and hours	1 part, 28 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	Theoretical foundations of fundamental processes that determine the physico-chemical properties of substances and materials used in modern energetics; and the field of their practical application.
Goals and objectives of the course in terms of competences and skills	The main objectives of the course are to familiarize students with the basics of elementary processes that control the physical and chemical properties of substances, including nanomaterials, used in modern energetics; to form students' understanding of the methods of synthesizing these materials; to teach students to understand the possibilities of practical application of nanomaterials in modern energetics.
Structure and tasks of independent studies	Preparation of presentations devoted to topics, which were not considered at lectures; written test work.
Recommended literature	1.García-Martínez, Javier. Nanotechnology for the Energy Challenge / Ed. by Javier García-Martínez. − Wiley-VCH, 2013. 2.de Souza, Flavio Leandro. Nanoenergy. Nanotechnology Applied for Energy Production / Ed. by Flavio Leandro de Souza, Edson Roberto Leite. − Springer Berlin Heidelberg, 2013. 3.Korkin, Anatoli. Nanotechnology for Electronics, Photonics, and Re-newable Energy / Ed. by Anatoli Korkin, Predrag S. Krstić, Jack C. Wells. − Springer Berlin Heidelberg, 2010. 4.Reddy, Boreddy. Advances in Nanocomposites − Synthesis, Charac-terization and Industrial Applications / Ed. by Boreddy Reddy. − In-Tech, 2011. 5.Archer, Mary D. Clean Electricity from Photovoltaics / Mary D. Archer. − World Scientific Publishing Company, 2001. 6.Klass, Donald L. Biomass for Renewable Energy, Fuels, and Chemi-cals / Donald L. Kalss. − Elsevier Inc., 1998. 7.Momoh, James. Smart Grid: Fundamentals of Design and Analysis / James Momoh. − Wiley-IEEE Press, 2012. 8. Krüger, Anke. Carbon Materials and Nanotechnology / Anke Krüger. − Wiley-VCH, 2010.
Course prerequisites	"Opto- and microelectronics".
Courses acquired before	"Solid State Physics", "Atomic-Molecular Processes", "Physical Chemistry of Nanosystems"

Course outline

Theme	Hours
Lectures	

Nanomaterials for photovoltaics, wind power, geothermal sources, tidal wave energy.	2
Nanomaterials for biomass energy, non-renewable sources, nuclear energy.	2
Nanomaterials for gas turbines, thermoelectricity.	2
Nanomaterials for fuel cells, hydrogen production, internal combustion engines, electric motors.	2
Nanomaterials for transmission of energy, superconductivity.	2
Nanomaterials for transmission lines based on carbon nanotubes, wireless power transmission.	2
Nanomaterials for smart grids, heat transfer.	2
Nanomaterials for electric energy, superaccumulators, chemical energy.	2
Nanomaterials for transformation (modification) and purification of fuel, fuel tanks, thermal energy, adsorption storage.	2
Nanomaterials for thermal insulation, air conditioning, lightweight construction.	2
Nanomaterials for industrial processes, lighting.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know real and potential possibilities of using nanomaterials to solve the main energy problems in the field of primary energy sources.	Ability to solve corresponding problems.
To know real and potential possibilities of using nanomaterials to solve the main energy problems in the field of energy production and conversion.	Ability to solve corresponding problems.
To know real and potential opportunities of using nanomaterials to solve the main energy problems in the field of energy distribution.	Ability to solve corresponding problems.
To know real and potential possibilities of using nanomaterials to solve the main energy problems in the field of energy storage.	Ability to solve corresponding problems.
To know real and potential possibilities of using nanomaterials to solve the main energy problems in the field of energy use.	Ability to solve corresponding problems.

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
1.	+	-	22	-	-	-	+	+	-	6

Course "Photovoltaics"
(for master students and 4-5 year students)
Faculty of Physics

General data

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Code	
Course title	Opto- and microelectronics
Course status in the programme	Obligatory
Course level	Master Studies
Course type	Academic
Field of study	Specialty "Functional nanomaterials"
Responsible instructor	Alexander V. Mazanik
Academic staff	Alexander V. Mazanik Mikhail S. Tivanov
Volume of the course: parts and hours	1 part, 30 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	Physical basics and principles of opto- and microelectronics.
Goals and objectives of the course in terms of competences and skills	The aim of this course is to reveal operation principles of the basic opto- and microelectronic devices, interrelation between the properties of used materials and operating parameters of corresponding structures, specificity of changing their properties under transition into a nanostructured state
Structure and tasks of independent studies	Preparation of presentations devoted to topics, which were not considered at lectures; written test work
Recommended literature	S.M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, Wiley, 2007
Course prerequisites	Theoretical bases of electricity, optics, material science, physics of semiconductors
Courses acquired before	Physics of Condensed Matter

Course outline

Theme	Hours
Lectures	
The basic equations describing processes in semiconductor devices. The equilibrium state of *p-n* junction.	2
Barrier capacitance of reverse-biased *p-n* junction. *p-n* junction under bias voltage. Mathematical model. Shockley equation.	2
Operation of diode in the low signal mode. Switching processes in diode. Large-signal operation regime. Breakdown of *p-n* junction.	2
Schottky diodes. Heterojunctions. Semiconductor photodiodes.	2
LEDs. Lasers with *p-n* junctions and heterojunctions.	2
Ideal MOS capacitor. Surface charge. Capacitance-voltage charactericties. Threshold voltage. Real MOS capacitor. Flat-band voltage.	2
MOSFET. Structure and operating principle. Operating characteristics.	2
Structure of bipolar transistor and its operation principle. Schemes of connection of bipolar transistor. Drift transistor	2

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Parameters of transistor in the DC regime. Operation of transistor in the low signal mode. Transistor in the switching mode. Thyristors.	2
Thermoelectrical devices. Efficiency of thermoelectrical energy conversion and thermoelectrical figure-of-merit. Modern approaches to obtain high-efficient thermoelectrical materials. Photothermoelectric systems of energy conversion.	2
Microelectronics and integrated circuits (ICs). Classification of ICs. Advantages and disadvantages of ICs. The main principles and stages of ICs production.	2
Prospects of development of CMOS technology. Size reduction and scaling principle. Problems of sub-50 nm technology. Beyond silicon based microelectronics.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know principles of operation of the basic structures of opto- and microelectronics	Ability to solve corresponding problems
To know advantages, disadvantages, characteristic operating parameters of modern structures of opto- and microelectronics	Ability to solve corresponding problems
To know principles of creating the basic structures of opto- and microelectronics	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
2.	+	-	24	-	-	-	+	+	+	6

Course "Spintronics"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Spintronics
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Functional Nanomaterials”
Responsible instructor	Mikhail G. Lukashevich
Academic staff	Mikhail G. Lukashevich
Volume of the course: parts and hours	1 part, 20 academic hours

Language of instruction	RU
Possibility of distance learning	Planned
Abstract	This course describes electronic structure, charge currier transport, as well as magnetic and galvanomagnetic properties of solids and structures in internal magnetic field. Spin-dependent scattering and tunneling in solids and inhomogeneous structures with magnetic ordering are ander consideration as a base for developing magnetoelectronics and spintronics devices.
Goals and objectives of the course in terms of competences and skills	To demonstrate to master-students the fundamental ideas magnetic and galvanomagnetic properties of solids, physical principles description in crystalline and non-crystalline solids; to give knowledge of their electronic structure and charge currier transport in internal magnetic field as a basic knowledge for developing magnetoelectronics and spintronics devises; to describe a role of size effects in the formation of properties of functional nanomaterials and low-dimensional solid-state devices; to get main competences and skills in the preparation and experimental study devises and structures with spin-dependent charge currier transport.
Structure and tasks of independent studies	At home must be prepared 2 tests and written 1 essay from 2 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	M.G. Lukashevich. Introduction to Magnetoelecronics//Minsk 2006 - P.64.
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics, statistical physics, electrodynamics, electric engineering, electronic devices
Courses acquired before	Electronic properties of solids, basics of material sciences and solid-state devices

Course outline

Theme	Hours
Lectures	
1. Introduction to the subject. The energy spectrum, energy distribution function and density of electron states in crystalline solids. Metals, semiconductors and insulators from the point of view of its band structure.	2
2. Coductivity mechanisms in solids. Metallic (diffusive) mechanism of conductivity. Processes of strong and weak localization, insulator –to-metal transition.	2
. 3. Magnetism of solids Introduction to magnetic properties of solids. Diamagnetism, paramagnetism, ferromagnetism. Langevin formulae and Kurie law. Exchange integral and kinds of exchange. Magnetization and magnetic hysteresis loop.	2
4. Introduction to magnetoelectronics and spintronics. Magnetic field and its characteristics. Electron energy spectrum and density of state in a strong magnetic field. Classical and quantizing magnetic fields.	2
5. The main physical effects of magnetoelectroncs and spintronics. Hall effect, magnetoresistive effect and magneto-diode effect in classical and quantizing magnetic fields at different conductivity mechanisms. Size effects in charge carriers transport and galvanomagnetic properties of solids.	2
6. Charge carrier transport in solids with magnetic ordering. Peculiarity of electron transport properties of solids with magnetic ordering. Kondo effect and effect of negative magnetoresistance.	2
7. Spin-dependent processes in charge carrier transport. Spin-dependent scattering and spin-dependent tunneling: physical models of giant, tunneling and colossal magnetoresistive effects.	2
8. Magnetic multilayers structures. Magnetic superlattises and structures: perspectives of their using in solid state electronic devices for magnetic field control,	2

measuring and computing.	

Learning outcomes and assessment

Learning outcomes	Assessment methods
To understand the basic ideas of electron band structure of solids and conductivity mechanisms on both sides of insulator-to-metal transition.	Ability to solve corresponding problems
To understand main physical processes charge transport in solids with different conductivity mechanisms in internal magnetic field.	Ability to solve corresponding problems
To understand the mechanisms of spin-dependent processes scattering and tunneling as a base for development spintronics devises.	Ability to solve corresponding problems
To be able to execute 2 written tests by 8 lectures (consisting of 5 questions every)	To give the right answers on 4 of 5 questions
At home must be done 1 essay	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	16	-	-	+	+	+	+	4

Course "Physics of Condensed Matter"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Introduction into Physics of Condensed Matter
Course status in the programme	Compulsory
Course level	Master level
Course type	Academic
Field of study	Material Science for Photonics
Responsible instructor	Alexander Fedotov
Academic staff	Gorbach Dmitry
Volume of the course: parts and hours	54 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	Fundamentals of solid state physics needed to explain main functional properties of photonic materials
Goals and objectives of the course in terms of competences and skills	To demonstrate to students the fundamental ideas and principles of physics of condensed materials (chemical bonds, atomic structure, zone model, main properties) for photonics
Structure and tasks of independent studies	At home must be solved 10 problems from main topics of the course within the framework of Controlled Independent Work (CIW) of students

Recommended literature	Chapter 4.1 of Electronic book “Photonics”
Course prerequisites	Fundamentals of general physics and mathematics, Quantum mechanics, Statistical Physics
Courses acquired before	Mechanics, Electricity

Course outline

Theme	Hours
Lectures	
Atomic structure of crystalline solids. Chemical bonds. Crystalline and space lattice. Closest ball packaging theory. Methods for atomic structure description.	4
Defects of crystalline lattice and their classification.	2
Atomic dynamics. The reciprocal space. Brillouin zone. Laue equations (interference condition).	2
Atomic oscillations in one-dimensional chain. The dispersion laws. Acoustic and optical oscillations.	4
Concept of phonons. The phonon spectrum. The number of possible oscillations (phonons) in a crystal.	2
Electric conductivity theory in metals. Drude model for free electron gas. Boltzmann kinetic equation. The difficulties of the classical theory of electrical conductivity.	4
Quantum theory of free electrons in metals (Zommerfeld model). Tight-binding approximation.	2
Zone model of solids. Single-electron and adiabatic approximations. Bloch wave-function.	2
Solution of the stationary Schrödinger equation for the Kronig-Penney model. Filling the energy bands by electrons. Dividing crystals on metals, dielectrics and semiconductors.	4
Electron dynamics in periodic lattice. Concept of effective mass.	2
Zone structure and statistics of semiconductors. Band structure in defect-free (intrinsic) semiconductors.	2
The influence of defects on the band energy spectrum of electrons in semiconductors.	2
Hydrogen-like impurities in the crystalline semiconductors.	2
Electrical conductivity of intrinsic and doped semiconductors. Hydrogen-like dopants.	2
Mechanisms of charge carriers’ scattering.	2
Electrical neutrality of semiconductors. Statistics of charge carriers in semiconductors. Equilibrium concentration of charge carriers in defect-free semiconductor crystals. The Fermi level in an intrinsic semiconductor.	2
Electrons and holes concentrations in doped semiconductors. Fermi level in doped semiconductor.	2
Control of independent work	4
Solution of problems	8

Learning outcomes and assessment

Learning outcomes	Assessment methods
To understand the basic ideas of different approaches to description of electronic properties of solids	Ability to solve corresponding problems
To understand the phonon concept for description of atomic vibrations in solids	Ability to solve corresponding problems
To understand the influence of defects on electrical properties of semiconductors	Ability to solve corresponding problems

Study subject structure

Part	Semester	Hours per semester	Tests	

	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	Control of independent work
1.	+	-	42	-	-	-	+	-	+	8

Course "Opto- and microelectronics"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Opto- and microelectronics
Course status in the programme	Obligatory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Functional nanomaterials”
Responsible instructor	Alexander V. Mazanik
Academic staff	Alexander V. Mazanik Mikhail S. Tivanov
Volume of the course: parts and hours	1 part, 30 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	Physical basics and principles of opto- and microelectronics.
Goals and objectives of the course in terms of competences and skills	The aim of this course is to reveal operation principles of the basic opto- and microelectronic devices, interrelation between the properties of used materials and operating parameters of corresponding structures, specificity of changing their properties under transition into a nanostructured state
Structure and tasks of independent studies	Preparation of presentations devoted to topics, which were not considered at lectures; written test work
Recommended literature	S.M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, Wiley, 2007
Course prerequisites	Theoretical bases of electricity, optics, material science, physics of semiconductors
Courses acquired before	Physics of Condensed Matter

Course outline

Theme	Hours

Lectures	
The basic equations describing processes in semiconductor devices. The equilibrium state of *p-n* junction.	2
Barrier capacitance of reverse-biased *p-n* junction. *p-n* junction under bias voltage. Mathematical model. Shockley equation.	2
Operation of diode in the low signal mode. Switching processes in diode. Large-signal operation regime. Breakdown of *p-n* junction.	2
Schottky diodes. Heterojunctions. Semiconductor photodiodes.	2
LEDs. Lasers with *p-n* junctions and heterojunctions.	2
Ideal MOS capacitor. Surface charge. Capacitance-voltage characterictics. Threshold voltage. Real MOS capacitor. Flat-band voltage.	2
MOSFET. Structure and operating principle. Operating characteristics.	2
Structure of bipolar transistor and its operation principle. Schemes of connection of bipolar transistor. Drift transistor	2
Parameters of transistor in the DC regime. Operation of transistor in the low signal mode. Transistor in the switching mode. Thyristors.	2
Thermoelectrical devices. Efficiency of thermoelectrical energy conversion and thermoelectrical figure-of-merit. Modern approaches to obtain high-efficient thermoelectrical materials. Photothermoelectric systems of energy conversion.	2
Microelectronics and integrated circuits (ICs). Classification of ICs. Advantages and disadvantages of ICs. The main principles and stages of ICs production.	2
Prospects of development of CMOS technology. Size reduction and scaling principle. Problems of sub-50 nm technology. Beyond silicon based microelectronics.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know principles of operation of the basic structures of opto- and microelectronics	Ability to solve corresponding problems
To know advantages, disadvantages, characteristic operating parameters of modern structures of opto- and microelectronics	Ability to solve corresponding problems
To know principles of creating the basic structures of opto- and microelectronics	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
2.	+	-	24	-	-	-	+	+	+	6

Course "Laser Physics"
(for master students and 4-5 year students)
Faculty of Physics

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General data

Code	
Course title	Laser Physics
Course status in the programme	Obligatory
Course level	Graduate level
Course type	Academic
Field of study	Specialty “Photonics”
Responsible instructor	Tolstik A.L.
Academic staff	Tolstik A.L.
Volume of the course: parts and hours	1 part, 34 academic hours (Lectures), 72 academic hours (Laboratory works)
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The course is aimed at studies of a theory of lasing, dynamic lasing modes; control methods for lasing frequency; operation principles of most common laser systems; using of laser systems in science and engineering, information technologies, medicine, etc.
Goals and objectives of the course in terms of competences and skills	Theoretical background in the essentials of laser physics; learning of the methods to generate high-power nano- and picosecond laser pulses, tuning methods for the lasing frequency; knowledge of the current problems of laser physics and of the latest tendencies in the development of laser technologies.
Structure and tasks of independent studies	At home must be written 1 essay within the framework of Controlled Independent Work (CIW) of students
Recommended literature	1. N.V. Karlov. Lectures in quantum electronics. M.: Nauka. 1983, 1988. 2. A.Yariv. Quantum electronics. M.: Mir. 1980. 3. F.Kachmarek. Introduction into laser physics. M.: Mir. 1981. 4. A.Yariv. Introduction into optical electronics. M.: Mir. 1983. 5. O.Zwelto. Principles of lasers. M.: Mir. 1984, 1990. 6. A.L.Tolstik, I.N.Agishev, E.A.Melnikova. Laser physics. Laboratory works. Mn.: BSU, 2006.
Course prerequisites	Nonlinear Optics, Fiber Optics, Coherent Optics and Holography
Courses acquired before	Optics, Molecular Spectroscopy, Luminescence

Course outline

Theme	Hours
Lectures	
Introduction into laser physics. History of the development of lasers. Principles of lasers operation and characteristics of laser radiation.	2
The notion of an active medium and methods of its creation. The active medium pumping processes (optical, electric, thermal, chemical, recombinational, etc.).	2
Optical pumping of active medium. Interaction between monochromatic radiation and resonant medium. Amplification factor. Saturation effect.	2
Schemes of optical pumping. Three- and four-level schemes of optical pumping. Amplification in solutions of complex organic	2

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compounds (dyes).	
Amplification in media with homogeneous and inhomogeneous broadening. Specificity of amplification in media with homogeneous and inhomogeneous broadening. Amplification saturation effect. Spectral hole burning.	2
Optical cavity and resonator modes. Open resonator. Resonator types. Stability condition and longitudinal resonator modes.	2
Quality factor of optical cavity. Longitudinal and transverse resonator modes. Loss in open resonators. Quality factor of resonator. Laser mode selection.	2
Stationary mode of laser operation. Conditions of passing to laser generation. Lasing power. Lasing threshold.	2
Characteristics of stationary generation. Optimal resonator coupling on stationary generation. Lasing spectrum.	2
Dynamic processes in lasers. Nonstationary mode of laser operation. Kinetic equations for lasing.	2
Free-running mode. Laser operation in the free-running mode. Spike structure of radiation.	2
Q-switching mode. Q-switching of optical cavity. Mathematical description of the lasing mode.	2
Active Q-switching method for optical cavity. Power, energy, and length of the lasing pulse on active Q-switching.	2
Passive Q-switching mode. Passive Q-switching method of optical cavity. Passive switches.	2
Mode locking method. Methods of active and passive mode locking.	2
Tunable lasers and frequency tuning modes. Tunable lasers when using diffraction gratings, prisms, Fabry-Perot interferometers.	2
Main laser types. Types of lasers distinguished by their active medium and by its pumping method.	2
Laboratory works	
Mode structure of *He-Ne* laser radiation	8
Neodymium doped yttrium aluminum garnet laser. Free-running mode.	8
Active Q-switching mode of laser cavity	8
Passive Q-switching mode	8
Passive mode locking mode	8
DPSS Laser	8
Tunable lasers	16
Semiconductor lasers and light-emitting diodes	8

Learning outcomes and assessment

Learning outcomes	Assessment methods
To understand the principal points in a theory of lasing and the properties of laser radiation; basic schemes used to attain different dynamic lasing modes; most common laser types and applications of laser radiation.	Ability to solve corresponding problems
To be able to calculate the lasing power of a laser operating in the continuous mode; the energy, peak power, and length of laser pulses in the Q-switching and mode-locking modes; ability to estimate the linewidth of a laser with intracavity dispersive elements (prism, diffraction grating, Fabry-Perot interferometer).	Ability to solve corresponding problems
At home must be done 1 essay	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	34	-	72		+	+	+	8

Course " Nonlinear optics"
(for master students and 4-5 year students)
Faculty of Physics

General data

Code	
Course title	Nonlinear Optics
Course status in the programme	Obligatory
Course level	Graduate level
Course type	Academic
Field of study	Specialty “Photonics”
Responsible instructor	Tolstik A.L.
Academic staff	Tolstik A.L.
Volume of the course: parts and hours	1 part, 24 academic hours (Lectures), 20 academic hours (Laboratory works)
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The course is aimed at studies of the fundamental physical principles of nonlinear optics. Students learn the mechanisms of optical nonlinearity in various media and the nonlinear effects leading to the transformation of light fields, wave generation at the sum and difference frequencies including the parametric light generation, second and higher harmonic generation, stimulated scattering of light, wavefront conjugation.
Goals and objectives of the course in terms of competences and skills	Theoretical background in the interactions between laser radiation and material; knowledge of different mechanisms of optical nonlinearity and of nonlinear-optical methods for light field transformations; methods to control the frequency and wave front of laser radiation; understanding of all possible applications of nonlinear optics in scientific research and engineering.
Structure and tasks of independent studies	At home must be written 1 essay within the framework of Controlled Independent Work (CIW) of students

Recommended literature	1.Y.R.Shen. Principles of nonlinear optics. M.: Nauka. 1989. 2.N.B.Delone. Nonlinear optics. M.: Physmatlit. 2003. 3.V.G.Dmitriev, L.V.Tarasov. Applied nonlinear optics. M.: Physmatlit. 2004. 4.A.L.Tolstik, I.N.Agishev, E.A.Melnikova. Laser physics. Laboratory works. Mn.: BSU. 2006. 5.S.N.Kurilkina, A.A.Minko. Nonlinear optics. Mn.: BSU, 2010.
Course prerequisites	Fiber Optics, Coherent Optics and Holography
Courses acquired before	Optics, Molecular Spectroscopy, Luminescence, Laser Physics

Course outline

Theme	Hours
Lectures	
Nonlinear optics origination and development history. Notion of a nonlinear medium. Maxwell equations for a light field in linear and nonlinear media. Classification of nonlinearities. Quadratic and cubic nonlinearity. Higher order nonlinearity.	2
Thermal nonlinearity. Nonlinearity of electrooptical crystals. Pockels effect. Orientational and induced Kerr effect. Electrostriction.	2
Nonlinear properties of a two-level resonant medium, absorption saturation. Kramers-Kronig relation and refractive index nonlinearity of a resonant medium.	2
Nonlinear properties of complex organic compounds, photorefractive and liquid crystals.	2
Light-beam self-focusing, autocollimation, and defocusing.	2
Effect of the second-harmonic generation. Efficiency of conversion to the second harmonic, coherent interaction length. Phase – matching condition and its fulfillment in birefringent crystals, angular width of synchronism.	2
Wave generation at the sum and difference frequency, optical rectification. Cascade generation of higher harmonics.	2
Parametric amplification in media with quadratic nonlinearity.	2
Operation principles of parametric oscillator. Parametric oscillator frequency-tuning methods. Lasing frequency stability.	2
Third-harmonic generation. Four-wave mixing and wave generation at the sum and difference frequency. Parametric amplification on four-wave interaction.	2
Rayleigh and Raman scattering of light by atoms and molecules. Spontaneous and stimulated Raman scattering. Stimulated Brillouin scattering.	2
Phase and wavefront conjugation. Notion of optical bistability, optical nutation, self-induced transparency, photon echo, squeezed light states.	2
Laboratory works	
Second harmonic generation	8
Stimulated Raman scattering	12

Learning outcomes and assessment

Learning outcomes	Assessment methods
To understand the mechanisms of optical nonlinearity and the principal optical phenomena (second and higher harmonic generation, self-focusing, stimulated Raman and Brillouin scattering , wavefront conjugation, and optical bistability)	Ability to solve corresponding problems
To be able to calculate nonlinear variations in the refractive index for various media and mechanisms of the interaction between laser radiation and material; calculations of the efficiency of the second	Ability to solve corresponding problems

and higher harmonic generation, threshold power and self-focusing length.	

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	24	-	20		+	-	+	8

3.2. Teaching/didactic materials uploaded to e-Library, virtual laboratory for student training, the instruction for its on-line usage

During the project implementation BSU team has developed the following presentations for lecture courses:

1. Composite nanostructured materials (9 presentations)
2. Physics and Chemistry of Surface (14 presentations)
3. Spintronics (3 presentations)
4. Introduction to Soilild State Physics (12 presentations)

These didactic materials are uploaded to the Moodle platform of BSU by the following Internet-adresses: https://dl.bsu.by/mod/folder/view.php?id=30904; https://dl.bsu.by/mod/folder/view.php?id=30905

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4. Grodno State University

4.1. Summary

Nanophotonics subject is the interaction of light with nanostructures. This course is organized in following manner. First, we consider the effect that determine the properties of nanostructures, namely, the quantum size effect. Next, consider how different features of quantum states of light and matter on the example of electrons.
The dimensions of the nanostructures is much less than the light wavelength, and all the features of this interaction should be considered, using the concept of the near field of the light wave. Near field occurs at all stages of the light waves from the transmitter to the receiver – for radiation stages, distribution, and finally interaction with matter. Firstly, it is the field in the vicinity of the radiating dipole. Secondly, it is a field near the aperture, the size of which is smaller than the wavelength of light. It can also be a field of the light waves near the interface of two materials. As such materials are the two dielectric with total internal reflection on the interface or a metal and a dielectric. All the effects listed above are caused by so-called *evanescent fields*, i.e. fields that decay at distances shorter than the wavelength of light. In the last sections of this chapter we consider what determines the properties of the near field and a what practical interest its represent.

4.2. Description of the courses / education programs

5. YaKSUG Master Course "Nanophotonics"

6. Faculty of Physics and Technics

7. ***General data***

Code	
Course title	Nanophotonics
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Modern methods and devices of physical measurements
Responsible instructor	Natallia Strekal
Academic staff	Alexander Maskevich Vitalia Stsiapura
Volume of the course: parts and hours	1 part, 64 academic hours
Language of instruction	RU
Possibility of distance learning	Planned

Co-funded by the Erasmus+ Programme of the European Union

Abstract	The task of this discipline is the acquisition of skills to solve problems related to issues of the propagation and interaction of light with nanostructured materials, the development of innovative thinking, scientific intuition and practical abilities of work on modern scientific equipment.
Goals and objectives of the course in terms of competences and skills	As a result of studying the academic discipline, the student must: -know: the diffraction limit of a near optical field, theoretical basis of the propagation of light through the aperture of a near-field microscope and in the near field of nanostructures; -be able to: solve the problem of the propagation of light, the localization of charge carriers, the quantum-size effect; distinguish between quantum and classical dimensional effects, which manifest themselves at different levels of organization of matter; -Know the skills: work on measuring the quantum yield and mean fluorescence decay time of nanoparticles, estimating nanoparticle sizes from absorption spectra, evaluating artifacts arising from imaging with an optical near-field optical microscope, to understand modern innovative literature.
Structure and tasks of independent studies	At home must be prepared 1 8 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	N. Strekal Nanophotonics. http://dl.bsu.by/, https://edu.grsu.by/
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics, statistical physics, electrodynamics, electric engineering, electronic devices
Courses acquired before	Optics, Physics of atom and atomic phenomena, physics of elementary particles

8. ***Course outline***

Theme	Hours
Lectures	
1. Introduction to the subject. The subject of nanophotonics, its place in the science of nanotechnology. The scale of the characteristic features, the relationship between the wavelength and the size of the region of propagation and / or localization of photons and charge carriers.	2
2. Quantum-size effect. Quantum-size effect of the first principles. Conditions for observing the quantum size effect in real structures. Classical and quantum dimensional effects..	2
Systems of reduced dimensionality. Localization of a particle in a one-dimensional potential well.	2
3. Density of states. Density of electron and photon states. Modification of the density of electronic states for systems of reduced dimensionality. The manifestation of the effect of the modification of the electronic state density in systems of reduced dimensionality	2
4. Interaction of light with nanostructures. Evanescent fields near the radiating dipole, small diaphragm and interface. Field of electric dipole. Diffraction of light at a diaphragm of subwave size. Full internal reflection of light. Overcoming the diffraction limit and near-field optical microscope	2
5. Theoretical approaches to the description of the optical near field. Theoretical approaches to the description of the optical near field.	2
The physical picture of the interaction in the near fieldtransferred from the physics of elementary particles, the concept of a dressed photon and the exchange of virtual photons between nanoparticles.	2

6. Interaction of light with plasmon nanostructures. Electronic excitations in nanostructured surfaces of silver and gold and their optical properties: electromagnetic waves on a plane interface between two media;	2
Propagation of electromagnetic waves on a rough metal-dielectric surface; the interaction of light with plasmons and chromophores adsorbed on the plasmon surface.	2
Basics of spectroscopy of plasmon resonance and plasmon-coupled fluorescence	2
7. Effects of light enhancing in the near field of nanostructures. The manifestation of spectral-size effects in the characteristics of secondary emission of molecules at the surface of plasmon films of silver and gold.	2
Mechanisms of Raman scattering enhancement. Fundamentals of Surface-Enhanced Raman Spectroscopy.	2
8. Practical applications of nanophotonics. High density data recording.	2
Application of fluorescent and plasmon nanoparticles in biomedical research.	2
Laboratory works	
1. The localization of the particle in a one-dimensional potential well	4
2. Quantum effects in low dimensional systems	4
3. Mechanisms of fluorescence decay in semiconductor nanoparticles CdSe / ZnS	8
4. Surface-enhanced Raman scattering of organic molecules	4
5.Confocal Raman microscopy study of biological tissues, stained with nanoparticles CdSe / ZnS	8
6. FT-IR spectrometry of nanoparticles CdSe/ZnS	4
7. FT-IR spectrometry of nanotubes	4

9. ***Learning outcomes and assessment***

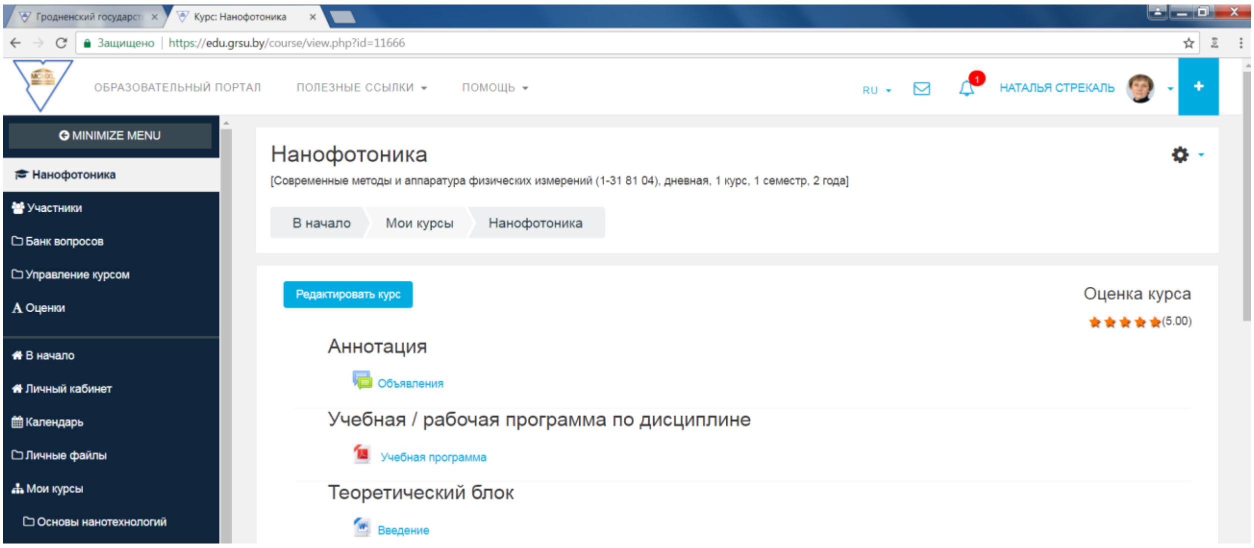
Learning outcomes	Assessment methods
To understand the basic ideas and approaches to characterization of quantum-confinement effect	Ability to solve corresponding problems
To understand main physical processes, proceeding in nanostructures under light interaction	Ability to solve corresponding problems
To understand the mechanisms of surface-enhanced of secondary radiation	Ability to solve corresponding problems
To be able to execute 1 control test by lecture course (consisting of 12 questions)	To give the right answers on 5 of 6 questions
To be able to perform 7 laboratory works	To submit a report and protect of each work

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	28	-	36	-	+	-	+	2

4.3. Teaching/didactic materials uploaded to e-Library, virtual laboratory for student training, the instruction for its on-line usage

All materials are posted on the educational portal at https://edu.grsu.by/

The following two figures demonstrate screen shorts of Nanophotonics course page in educational portal.



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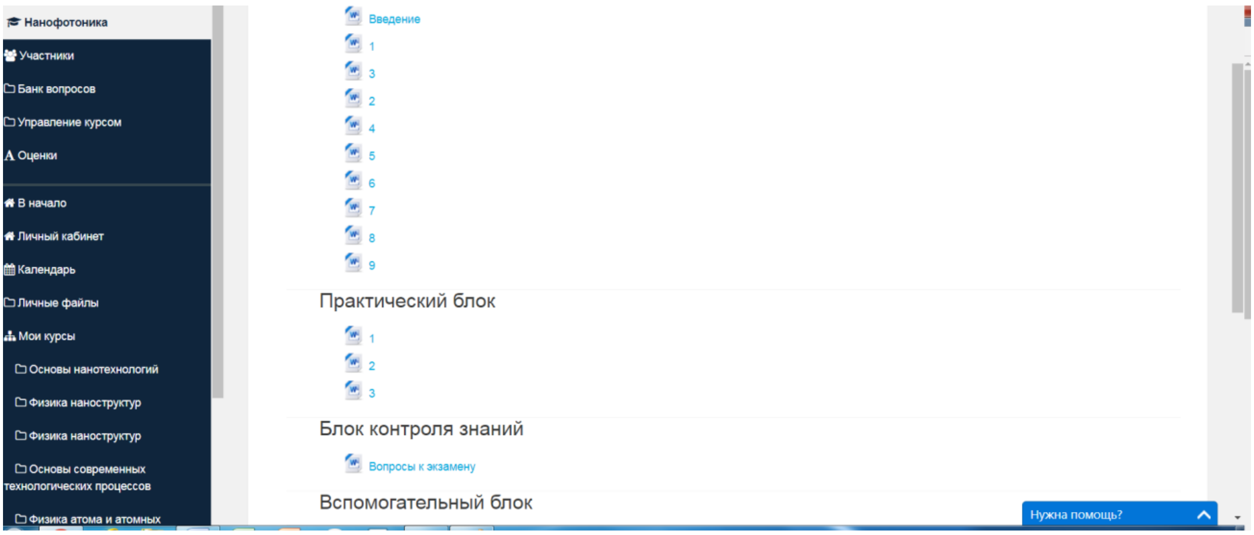

The instruction for its on-line usage are upper help button in the top line of the page and in bottom right corner.

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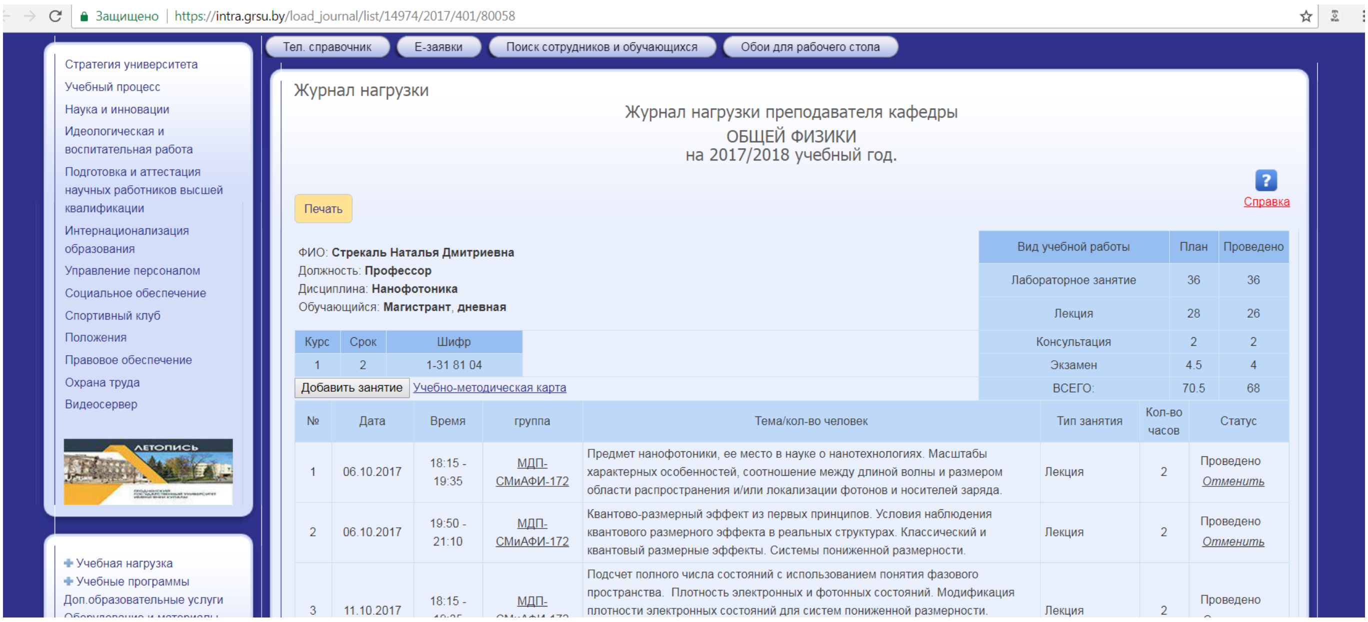
The training journal also is posted on the intranet intra.grsu.by. The following two figures demonstrate screen shorts of training journal page in the intranet of GrSU.



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4.4. Attachments

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5. Gomel State University

5.1. Summary

To improve education in Physics in Belarusian universities and to make it closer to Bologna system, GSU has developed new Curricula for 2-year masterships by specialties 1-31 80 05 - Physics and also renewed training programs 1-year master for the previous 5+1 system 1-year master. The description of new Curricula present in the Annex 1-2. These Curricula are divided on 3 parts (components): Preliminary State (mandatory) component, University component and Courses at students` option.

5.2. Description of the courses / education programs

Course " Sol-gel synthesis of functional materials "
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 362017-178/уч от 07.06.2017
Course title	Sol-gel synthesis of functional materials
Course status in the programme	Compulsory
Course level	Master studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	V.E. Gaishun
Academic staff	V.E. Gaishun
Volume of the course: parts and hours	40 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	Due to the rapid development in the last several decades of a number of the knowledge-intensive industries there was a need for highly qualified specialists in the field of synthesis of various functional materials sol-gel by method. These functional materials can be synthesized in the form of vitreous materials, ceramics, thin-film coatings, powders and can be applied in all directions of the modern electronics engineering, micro and a nanoelectronics, fiber optics, other industries. A number of the production enterprises of Republic of Belarus apply sol-gel technology in technological processes. Thus, studying of this course is reasonable as the received data can be useful to experts during future professional activity.
Goals and objectives of the course in terms of competences and skills	The purpose of studying consists in assimilation by students of the main regularities sol-gel of processes of synthesis of the functional materials. One of priority problems of a course is formation at the studying knowledge and competences on the basis of which

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	further it is possible to develop more profound and detailed studying of specialized courses.
Structure and tasks of independent studies	When studying a course such sections as physical and chemical bases alkoksidny process sol-gel are considered; features of synthesis of monolithic materials; rheology transition sol-gel; physical and chemical features of process of drying and baking of xerogels; sol-gel method of synthesis of thin films; electrophysical, optical and structural properties sol-gel of systems; ranges of application sol-gel of systems. Problems of studying of discipline: to study the maintenance of a course, to acquire and comprehend the main regularities process sol-gel.
Recommended literature	1. Submonetary E.N., Boyko A.A. Sol-gel synthesis of an optical quartz glass: Monograph. – Gomel: Establishment of education "GGTU of P.O. Sukhy", 2002. – 210 pages. 2. Tarasyuk E.V., Shilova O.A., Hashkovsky S.V. Sol-gel technology of receiving glassceramic and hybrid coverings. – Magnitogorsk: "The Magnitogorsk state technical university of G.I. Nosov", 2009. – 103 pages.
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, electrodynamics, electric engineering, solid state physics, phase transformations in solids, physics and chemistry of surface.
Courses acquired before	Basics of solid-state physics and material sciences

Course outline

Theme	Hours
Lectures	
1. PHYSICAL AND CHEMICAL BASES OF ALKOXY SOL-GEL PROCESS Basic concepts and definitions. Sol-gel process on the basis of tetroethyltosilicate. Main stages of sol-gel process. Hydrolysis and polycondensation. Gelation. Maturing and drying of gels. Maturing and drying of gels. Sintering of xerogels. Possibility of dehydration of xerogels during heat treatment.	2
2. RHEOLOGY TRANSITION SOL-GEL Rheological properties of sol-gel systems. Dynamic viscosity. Thixotropic and rheopex properties of sol-gel systems. Effect of doped additives on the rheological properties of sol-gel systems. Rheological properties of hybrid systems. Rheological properties of silicate systems. Methods for measuring the viscosity properties of sol-gel systems.	2
3. PHYSICAL AND CHEMICAL FEATURES OF PROCESS OF DRYING AND BAKING OF XEROGELS Physicochemical features of drying processes of voluminous xerogels. Pore size distribution. Capillary stresses. Influence of surfactants on drying speed. Vacuum drying. Sintering in air. Sintering in an atmosphere of inert gases. Sintering in freon. Sintering in a reducing atmosphere.	2
4. SOL-GEL METHOD OF SYNTHESIS OF THIN FILMS Synthesis of film-forming sols. Preparation and properties of vitreous and glass-ceramic coatings. Hybrid organo-inorganic coatings. Production of multilayer coatings. Synthesis of functional coatings. Influence of the surface structure of the substrate on the properties of the formed coatings. Coating methods.	2
5. FEATURES OF SYNTHESIS OF MONOLITHIC MATERIALS SOL-GEL BY METHOD Synthesis of bulk glasses by sol-gel method. Features of drying and sintering monolithic blanks xerogels. Synthesis of glass-ceramic by sol-gel method. Indirect sol-gel method. Equipment used in the synthesis of monolithic materials by the sol-gel method.	2

6. CERAMIC NANOCOMPOSITES Preparation of oxide materials. Ceramic method. Formation of powders and nanopowders. Methods of obtaining ceramic materials with the help of sol-gel processes. Comparison of traditional ceramic technology with sol-gel method for obtaining nanocomposites.	2
7. ELECTROPHYSICAL, OPTICAL AND STRUCTURAL PROPERTIES SOL-GEL OF SYSTEMS Electrophysical, optical and structural properties of sol-gel films, the possibility of their modification by introducing organic modifications. Electrophysical, optical and structural properties of sol-gel glasses, ceramics, powders. Methods for studying the physical properties of sol-gel systems.	2
8. RANGES OF APPLICATION SOL-GEL OF SYSTEMS Application activated and clear quartz sol-gel of glasses. Ranges of application of protective, clarifying and others sol-gel of films. Ranges of application of the nanopowders synthesized sol-gel by method. Ranges of application of the ceramics and nanoceramics synthesized sol-gel by method.	2
Lab.	
1. Obtaining and research of properties sol colloid systems.	4
2. Synthesis of volume xerogels by sol-gel method.	4
3. Studying of process of drying of xerogels.	4
4. Drawing thin sol-gel films in various ways and their heat treatment.	4
5. A sintering of the xerogels synthesized by sol-gel method.	4
6. Research of physical properties of sol-gel systems.6 Methods of measurement of viscous properties of sol-gel systems.	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
nobility: *- the basic concepts and definitions characterizing sol-gel process;* *- possibilities of application technology sol-gel in the modern industry;*	Ability to solve corresponding problems
to be able: *- to apply a sol-gel method to synthesis of the functional materials;* *- to synthesize sol-gel materials with the given physical properties;* *- to use the modern devices, the experimental methods for studying of regularities process sol-gel;*	Ability to solve corresponding problems
to own: *- by methods of theoretical and pilot study sol colloid systems;* *- by methods of data interpretation.*	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	-	+	16	-	24	-	-	-	+	-

Course " Physics of wave processes "
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 36-2017-206/уч от 07.06.2017
Course title	Physics of wave processes
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	Girgel S.S.
Academic staff	Girgel S.S.
Volume of the course: parts and hours	40 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The main aim of the course is to define the basis of modern Physics using rather simple model examples. The existence of the theory of oscillations and waves, since the complete branch of physics today is something obvious. Main lectures should be based not on factual data as they are, and not on a mathematical apparatus, but on a deep analysis of contents and development of the main physical theories, the concrete analysis of the concepts with which the physicist works, i.e. everything that is the center of physical thinking and that is pretty often mentioned accidentally or even ignored in regular textbooks.
Goals and objectives of the course in terms of competences and skills	Considering the uniform approach of the modern physics: to consider the main wave phenomena and processes happening in the nature, to establish connection between them, to output fundamental laws and to receive their expression in the form of the mathematical equations. Further, it is necessary to teach undergraduates of theoretical and applied scientific research in the field of physics of waves.
Structure and tasks of independent studies	Making presentations devoted to topics, which were not discussed during the lectures; doing tests
Recommended literature	1. Aleshkevich V. A., Dedenko L.G., V.L. Loaves. Fluctuations and waves. - Lectures. M.: MSU, 2001. – 144 pages. 2. Arnold V.I. Theory of accidents. M.: Science. 1990. 127 pages 3. Karlov N.V., Kirichenko N.A. Fluctuations, waves, structures. M, Fizmat, 2003. 496 pages.
Course prerequisites	quantum mechanics, thermal dynamics, statistical physics, electrodynamics
Courses acquired before	Methods of mathematical physics

Course outline

Theme	Hours

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Lectures	
1 Fluctuations Community of oscillating and wave processes in nature. Basic concepts and mathematical apparatus of a vibration theory. Basic concepts of physics of vibrating systems. Linearity and principle of superposition. Kinematics of fluctuations. Dynamic Systems (DS) and their classification. The linear fluctuations. Concepts of stability and instability of balanced states and periodic movements.	2
2 Dynamic systems and free fluctuations Dynamic systems of the 1st order. Total characteristic and classification of dynamic systems of the 2nd order. Ffree fluctuations in conservative dynamic system with one degree of freedom. Free fluctuations in the nonconservative dynamic system of the 2nd order. Classification of singular points.	2
3 Theory of accidents Methods of a qualitative analysis of the linear and non-linear dynamic systems of a general view. Elements of the theory of accidents. Features, bifurcations and the simplest accidents. Assembly, fold, dovetail. Stability loss. Caustics, wavefront sets and their metamorphoses.	2
4 Waves in dispersive media Physical nature of dispersion. Models of waves in nondispersive and dispersive media. Waves in plasma. Distribution of a wave packet in the linear dispersive medium. Energy and impulse of a wave package. Phase and group speed. The running and standing waves.	2
5 Non-linear physics and non-linear waves Description of the linear waves the simple differential equations. A principle of superposition for the linear waves. Wave dispersion and dissipation of energy. Quasilinear wave equations. Waves on the surface of liquid. Equation of Kortevega-de-Vrisa and non-linear waves. Dependence of speed of a non-linear wave on amplitude.	2
6 Simple non-linear waves Stability and instability of waves. Simple non-linear waves. Non-linear waves in the dissipative nondispersive environment. Simple non-linear wave of Riemann. The non-linear phenomena at an advance of waves. Shockwaves and their structure. Non-linear waves in disperse non-dissipative environment. Cnoidal waves. Equation of Byurgersa-Kortevega-de-Vrisa. Byurgers's equation.	2
7 Non-linear equations and solitons Non-linear wave equations. Significantly non-linear equations. Kortevega Vriz's (KDV) equation and solitary waves. Express, specifically non-linear private decisions – the solitons localized in space and in time. Solitons and their classification. Tsunami. Stability and instability of waves. Non-linear Schrodinger equation (NSh). Sin-Gordon equation. Dispersive decisions. Stationary decisions.	2
8 Non-linear waves in environments with dispersion and their interaction Influence of nonlinearity and the frequencies dispersion on an advance of waves. Waves in anisotropic media. Non-linear optical medium. Non-linear interactions of waves and oscillation of harmonicas. Synchronism conditions in crystals.	2
Practical	
1 Damped oscillations The linear oscillator with attenuation. The linear and non-linear fluctuations with one and two degree of freedom. Beats. Fluctuations with many degree of freedom. Fluctuations of a string.	2
3 Forced oscillations Forced oscillations in the linear and non-linear dynamic systems (DS) of the 2nd order. Exaltation of the linear oscillator by acyclic force. Resonance. Non-linear resonance. Multiplication of frequency.	2
4 Parametrical fluctuations and self-oscillations Parametrical fluctuations. Equations of Hill and Mathieu. Floquet's theorem. Parametrical resonance and conditions of its	2

emergence. Self-oscillations. Modes of initiation of self-oscillations. The compelled synchronization. Fluctuations in systems with several degree of freedoms.	
5 Physics of the linear waves Wave processes and ways of their classification. Value of physics of wave processes for methods of the modern scientific research. Basic concepts of physics of the linear wave processes. Examples of wave motion. Scalar wave equation and scalar plane waves. Electromagnetic waves.	2
6 Equation of Helmholtz Scalar equation of Helmholtz and methods of its decision. Separation of variables. One-dimensional plane waves. and spherical waves. Scalarization of the vector equation of Helmholtz. Use of potentials and vectors of Hertz.	2
7 Cylindrical electromagnetic waves The equation of Helmholtz in a cylindrical frame. Separation of variables. One-dimensional cylindrical waves. Bessel, Neumann and Hankel's cylindrical waves.	2
8 Spherical electromagnetic waves One-dimensional spherical waves. Separation of variables. The associated and surface harmonics of Legendre. Surface harmonics of Bessel. The running and standing spherical waves.	2
9 Maxwell's equation and vector wave equation Maxwell's equations. Vector wave equation. Plane simple harmonic waves. Types of polarization of vector waves.	2
10 Wave diffraction and wave bunches Wave bunches. Parabolic approximation. Circular bunches are Gaussian. Method of a point source. Elliptic bunches with the composite astigmatism are Gaussian. Wave bunches of Hermite Gauss as solution of the parabolic equation. Reference fashion of Laguerre Gauss.	2
11 Wave bunches of Bessel Gauss The solution of the parabolic equation in the form of Bessel and Bessel Gauss paraxial wave bunches. Properties of bunches of Bessel Gauss and their application. Receiving methods. Other types of bunches. Kummer Gauss bunches, Mathieu Gauss, Weber Gauss, etc.	2
12 Fractals Concept of a fractal. Wave processes in the systems described by the non-linear equations of diffusion type. A concept about self-organization. Emergence of structures in non-linear environments Casual waves and emergence of stochasticity. Concept of a fractal. Classification of fractals. Waves in fractal environments.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
nobility: *– original positions and applications of physics of wave processes;* *– methods of a qualitative analysis of dynamic systems;* *– bifurcations and the simplest accidents;* *– methods of an analytical integration of non-linear wave tasks;*	Ability to solve corresponding problems.
to be able: *– to use methods of a vibration theory and waves for the description of actual systems and to apply the gained knowledge in self-contained developments;*	Ability to solve corresponding problems.

– to transfer knowledge gained in the field of physics of wave processes to developments in the field of the modern technologies;	
to own: *– skills of the qualitative and quantitative description of oscillating processes in dynamic systems;* *– knowledge of the main approximations and methods of an integration of non-linear wave tasks.*	Ability to solve corresponding problems.

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
1.	-	+	16	24	-	-	-	+	+	-

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Course " Modulators of laser radiation "
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 34-2017-175/уч от 07.06.2017
Course title	Modulators of laser radiation
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	V.N. Myshkovec
Academic staff	V.N. Myshkovec
Volume of the course: parts and hours	46 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	Physical basics and principles of opto- and microelectronics.
Goals and objectives of the course in terms of competences and skills	Mastering the basics of laser technique and technology. – to become familiar with basic concepts of technological processes occurring under the influence of continuous and pulse-periodic laser radiation fluxes; – to learn about technological features of laser technological processes; – to develop skills in determining the energy, time, optical and gas dynamic parameters of laser technological processes.
Structure and tasks of independent studies	Making presentations devoted to topics, which were not discussed during the lectures; doing tests
Recommended literature	E.D. Karikh, I.S. Monak, Quantum radiophysics, Minsk, 2010. 367 p. Ignatov A. N. Optoelectronic tools and devices. – M.: «Eco-Trends», 2006.
Course prerequisites	Theoretical bases of electricity, optics, physics of semiconductors
Courses acquired before	Physics of lasers

Course outline

Theme	Hours
Lectures	
Modulation of laser radiation Types of modulation of laser radiation: amplitude, frequency, phase and polarization	2
Physical operation principles of laser radiation modulators. Physical principles of modulators. Characteristics and parameters: broadband, dynamic range, modulation depth, modulating signal power, power consumption	2
Extracavity laser radiation modulators Acoustooptic modulators: diffraction on running modulated waves and on standing ultrasonic waves. Characteristics of materials having an electro-optical effect.	2
Magnetooptical extracavity modulators Modulation methods that use the principles of splitting and shifting the working energy levels of atoms, molecules and crystals	2

Intracavity prism modulators Optical-mechanical Q-switches with a rotating prism	2
Electro-Optical Intracavity Modulators of Laser Radiation. Electro-optical Q-switches (EOPS) on the linear Pockels effect and on the quadratic Kerr effect. Electro-optical elements based on the effects of Pockels and Kerr.	2
Acoustooptic intracavity laser light modulators Diffraction of light by ultrasonic waves. Bragg's diffraction. Bragg's angle. Acoustooptic Q-switches	2
Phototropic intracavity laser light modulators Phototropic media: solutions of phthalocyanines, KS-19 glasses, uranyl glasses (with an admixture of uranium salts), and polymethine dyes	2
Optical quantum generators with Q-switching. Physical processes in a laser with Q-switching. Time operation modes of solid-state lasers: Q-switching mode of the laser cavity and the mode synchronous regime	2
Laboratory	
Extracavity and intracavity modulators of laser radiation	4
Optical-mechanical laser cavity Q-switches	4
Electro-Optical modulators of laser radiation on the linear Pockels effect	4
Electro-Optical modulators on the quadratic Kerr effect	4
Acoustooptical diffraction modulators of laser radiation on progressing modulated waves	4
Acoustooptical diffraction modulators of laser radiation on standing ultrasonic waves	4
Phototropic (passive) laser radiation modulators	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
to know the features of laser technological processes	Ability to solve corresponding problems
to be able to determine the energy, time, optical and gas dynamic parameters of laser technological processes	Ability to solve corresponding problems
to know the fundamentals of technological processes occurring under the influence of continuous and pulsed-periodic flows of laser radiation	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
1		+	18	-	28	-	+	+	+	6

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Course "Industrial lasers"
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 34-2017-180/уч от 07.06.2017
Course title	Industrial lasers
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	V.N. Myshkovec
Academic staff	V.N. Myshkovec
Volume of the course: parts and hours	46 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	Acquiring the basics of laser technique and laser technologies
Goals and objectives of the course in terms of competences and skills	Mastering the basics of laser technique and laser technologies. – to become familiar with the basics of technological processes occurring under the influence of continuous and pulse-periodic laser radiation fluxes; – to understand the technological features of laser technological processes; – to develop skills in determining the energy, time, optical and gas dynamic parameters of laser technological processes.
Structure and tasks of independent studies	Making presentations devoted to topics, which were not discussed during the lectures; doing tests
Recommended literature	E.D. Karikh, I.S. Monak, Quantum radiophysics, Minsk, 2010. 367 p. Ignatov A. N. Optoelectronic tools and devices. – M.: «Eco-Trends», 2006.
Course prerequisites	Theoretical bases of electricity, optics, physics of semiconductors
Courses acquired before	Physics of lasers

Course outline

Theme	Hours
Lectures	
Physical bases of laser radiation interaction with matter Radiation absorption and energy transfer. Heating of the material without destruction. Destruction of materials	2
Industrial technological laser equipment for material processing Technological features of laser radiation. Requirements for industrial process lasers	2
Optical systems of laser technological installations General provisions for calculating the parameters of forming systems. Optical systems for processing materials along the contour using two movable mirrors	2
Laser pulse welding of metals and alloys The effect of laser radiation on metals and alloys. Physical features of metal melting under the action of laser radiation	2

Technological features of laser welding of various structural materials Connection types. Features of designing parts for laser welding. Laser welding of aluminum and magnesium alloys.	2
Gas laser cutting (GLC) of metals and alloys. Technological equipment for laser cutting of metals Cutting metals in a jet of oxygen. Parameters and indices of the GLC process. Energy parameters of the process	2
Laser separation of non-metallic materials Features of laser materials separation. Laser separation of dielectric materials	2
Laser hardening of metals and alloys by pulsed and continuous radiation Processing schemes for hardening by pulsed and continuous laser radiation. Choice of modes. Technological characteristics of the process	2
Laser technologies in microelectronics and nanoelectronics Laser deposition of thin films. Laser annealing and alloying of semiconductors. Laser processing of film materials	2
Practical	
Optical systems of laser technological installations	
Focusing of laser radiation	
Setting engineering targets for numerical analysis of thermal processes and methods for theoretical study of thermal fields during laser processing	
Practical tasks of the engineering class for the calculation of thermal fields during laser processing	
Laboratory	
Physical and technological features of processing metals and alloys by laser radiation.	4
Laser hardening of steels by pulsed radiation of solid-state lasers.	4
Laser doping of alloys with metallic and non-metallic components.	4
Pulsed spot and seam welding of metals.	4
Laser cutting of metals by pulsed laser radiation	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
to know physical operation principles of laser radiation modulators	Ability to solve corresponding problems
to know physical principles of operation and the construction of industrial process lasers	Ability to solve corresponding problems
to know physical processes occurring when processing materials by laser radiation	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam (test)	
1	-	+	18	8	20	-	+	+	+	6

Course "Metamaterials "
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 35-2017-176/уч от 07.06.2017
Course title	Metamaterials
Course status in the programme	Compulsory
Course level	Master level
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	I.V. Semchenko
Academic staff	I.V. Semchenko
Volume of the course: parts and hours	40 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	The discipline contents covers a range of issues related to the features of the development and design of metamaterials for the microwave and terahertz wavelength ranges, as well as their practical application.
Goals and objectives of the course in terms of competences and skills	Training of highly qualified scientists possessing professional knowledge and skills as well as practical skills, personal and business qualities necessary for successful scientific research in the field of radiophysics and optics
Structure and tasks of independent studies	4 problems from main topics of the course within the framework of Students’ Individual Work (SIW) must be solved at home
Recommended literature	Chapter 6.5 of Electronic book “Photonics”
Course prerequisites	Fundamentals of general physics and mathematics, Quantum mechanics, Statistical Physics
Courses acquired before	Optics, Electricity

Course outline

Theme	Hours
Lectures	
Introduction Metamaterials. Properties of metamaterials. Differences of metamaterials from photonic crystals.	2
Two and three-dimensional metamaterials Two-dimensional and three-dimensional metamaterials samples. The origin. Typical application. Features of metamaterials production.	2
Metamaterial as a medium with simultaneously negative values of dielectric permittivity and magnetic permeability Classification and comparison of various materials depending on signs of dielectric permittivity and magnetic permeability. The use of chiral elements. The problem of the "left environment". Ability to create media with a negative refractive index. The Lens of Veselago.	2
The application of metamaterials for objects camouflage using the wave flotation method Camouflage concept. Designing of camouflage coatings. Fundamentals of transformational optics. Experimental camouflage masking devices.	2
The optimum shape of the helix as a metamaterial element Equality of dielectric, magnetic and chiral susceptibilities of the helix. Calculation of electric dipole and magnetic moments of the helix. The condition of the main frequency resonance. The radiation condition for the helix of a circularly polarized wave. Optimum angle of helix. The equations of connection	2

Metamaterials for a microwave band on the basis of chiral elements The application areas of metamaterials for the microwave range. The technology of manufacturing metamaterials for the microwave range. Modeling and experimental study of the properties of metamaterials for the microwave range	2
Chiral metamaterials for the terahertz band on the basis of helix elements The method of exact 3D nanostructuring. Simulation of the properties of an artificial anisotropic structure. The results of experimental studies. Low-reflective metamaterials with compensated chirality for the terahertz range.	2
Low-reflection metamaterials with compensated chilarity for terahertz band Methods of compensation for chirality. The technology of metamaterial production with compensated chirality. Numerical simulation of metamaterial properties with compensated chirality. Results of an experimental study of metamaterials with compensated chirality.	2
Laboratory	
Calculation and simulation of metamaterials with simultaneously negative values of dielectric permittivity and magnetic permeability.	4
Calculation and simulation of metamaterials to camouflage objects using the wave flow method	4
Calculation of the optimal shape and parameters of the helix for different wavelength ranges	4
Simulation of metamaterial properties for the microwave range	4
Simulation of the chiral metamaterials properties for the terahertz range	4
Simulation of low-reflective metamaterials with compensated chirality	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
to understand the basic ideas of different approaches to description of metamaterials	Ability to solve corresponding problems
to describe the negative refraction of light in metamaterials	Ability to solve corresponding problems
to understand the influence of inclusions on the properties of metamaterials	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	Control of independent work
1.	+	-	16	-	24	-	+	-	+	6

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Course "Ellipsometry"
(for 2-year master)
Faculty of Physics and IT

General data

Code	УД 36-2017-177/уч от 07.06.2017
Course title	Ellipsometry
Course status in the programme	Compulsory
Course level	Master level
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	N.N. Fedosenko
Academic staff	N.N. Fedosenko
Volume of the course: parts and hours	40 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The course deals with the solution of new engineering problems arising during the development and manufacturing application of progressive methods for optical control of material parameters
Goals and objectives of the course in terms of competences and skills	Mastering the basics of modern methods of materials research based on laser physics and the principles of modern laser devices.
Structure and tasks of independent studies	4 problems from main topics of the course within the framework of Students’ Individual Work (SIW) must be solved at home
Recommended literature	Chapter 6.5 of Electronic book “Photonics” A.V. Khomich, V.I. Kovalev, E.V. Zavedeev, R.A. Khmelnitskiy, A.A. Gippius. Spectroscopic ellipsometry study of buried graphitized layers in ion implanted diamond. Vacuum78 (2005) 583-587.
Course prerequisites	Fundamentals of general physics and mathematics, Quantum mechanics, Statistical Physics
Courses acquired before	Optics, Electricity

Course outline

Theme	Hours
Lectures	
Basic principles of laser ellipsometry. Basic equation of ellipsometry. The principle of the laser. The role of the resonator. Laser radiation properties. Lasers application. The basic equation of ellipsometry	2
Laser ellipsometers. Devices of laser radiation polarization. Polarizers and analyzers. Measurement of laser radiation parameters.	2
Spectral ellipsometers. The principle of the spectral ellipsometer. Polarization principles of electromagnetic radiation in a given spectral interval	2
Means of radiation for a spectral ellipsometer. LED linear. Spectral characteristics of LED. Diffraction gratings	2
Lasers in ellipsometry Method of Q-switching, parameters of giant pulses. Open resonators. Methods of calculation. Modes of the resonator.	2
The dynamics of tunable lasers Balance equations of multimode lasers. Spectrum of stationary generation. Methods of modes selection.	2
Methods of generating short laser pulses. Modes synchronization; parameters of pulses, the effect on the accuracy of ellipsometric measurements	2
Semiconductor lasers with different wavelengths for spectral ellipsometry. Semiconductor lasers of different wavelengths in a given spectral interval. Perspective devices of semiconductor laser systems for spectral ellipsometry.	2

Laboratory	
The investigation of optical constants of multilayer thin coatings by means of laser ellipsometry	4
Adjusting the Fabry-Perrot resonator	4
Measurement of laser pulse duration	4
Measurement of the repetition rate of the laser pulse.	4
Measuring the divergence of laser radiation.	4
Laser ellipsometer LEF-3M. Operation principle and measurement of optical constants	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
to be aware of modern operation principles of optical ellipsometers using laser radiation	Ability to solve corresponding problems
to be able to perform measurements of the main parameters of laser radiation: wavelength and polarization of laser radiation	Ability to solve corresponding problems
to be able to organize and carry out research using modern laser and spectral ellipsometers	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	Control of independent work
1.	+	-	16	-	24	-	+	-	+	6

Course " The modern ideas of matter structure "
(for 1-year /2-year master)
Faculty of Physics and IT

General data

Code	УД 33-2015-655/уч от 28.05.2015
Course title	The modern ideas of matter structure
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	N.V. Maksimenko
Academic staff	N.V. Maksimenko

Volume of the course: parts and hours	34 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The physics of elementary particles studies the smallest building blocks of the world around us and the basic forces acting between them. This task is closely connected with the ancient ambition of a man to find simple and general laws that can explain all the diversity and complexity of natural phenomena. The simplest example of such common description can be obtained by introducing the concepts of fundamental particles and interactions between them. Then, there is some hope to explain macroscopic physical and chemical processes in the language of these basic components of matter.
Goals and objectives of the course in terms of competences and skills	The course objective is to master the basic principles of the theory of fundamental particles and their interactions.
Structure and tasks of independent studies	Problems of the discipline are: – acquaintance with the main properties of the fundamental particles and their interactions on the basis of phenomenological approach; – understanding the concept of interactions in the modern quantum field theory; – the analysis of any process with participation of hadrons and leptons with regard to the laws of preservation of quantum numbers and C - P-, T - parities using Feynman charts; – mastering bases of the continuous and discrete transforms, models of violation of T - and CP-invariances; – formation of skills on creation of hadrons from quarks and a systematics of the fundamental particles.
Recommended literature	1. Sadovsky M.V. Lectures on the quantum field theory. / M.V. Sadovsky. Moscow Izhevsk 2003 - 479 pages. 2. N.V. Krasnikov, V.A. Matveev "New physics on a Large Hadron Collider". URSS. Moscow. 2011. 3. M.I. Vysotsky "The current state of an elementary particle physics". Arxiv:1405.5./1/[physics. Gen. - p h]. 2014.
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics, statistical physics, electrodynamics, physics of atom and atomic phenomena, nuclear physics and elementary particle physics
Courses acquired before	quantum mechanics, nuclear physics and elementary particle physics

Course outline

Theme	Hours
Lectures	
1. Lagrangian and Hamilton description of the continuous systems. The generalized coordinates. Equations of motion. Action function variation. Equation of Lagrange Euler. Examples of a Lagrange function. Relativity of Galileo. Symmetry of space and time, conservation laws. Shift of time and conservation of energy. Approximation of the continuous system by means of discrete. Transition from a lumped parameter system to the continuous. Equations of motion for the continuous systems.	4
2. Scalar fields. Equation of the scalar real field. Dynamic variables. Pulse representation. Physical interpretation of dynamic variables. Equation of a complex scalar field. Current density vector. Pulse representation of the scalar complex field. Physical interpretation of physical variables.	8
3. Maxwell's and Dirac equations. Maxwell's equation and D'Alembert. Lagrangian description of an electromagnetic field. Dynamic variables of an electromagnetic	10

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field. Spin properties of a field of vectors. Gage invariance. Pulse representation of an electromagnetic field. Equation of Dirac. Physical interpretation of decisions. Solution of the equation of Dirac. Properties of γ-matrixes. Lagrangian description of the spinor field. Definition of dynamic variables.	
4. Lagrangian description of the interacting fields. The principle of a local gage invariance in the theory of the interacting fields. A current conservation law as a result of the principle of a gage invariance. The solution of the equations for the interacting fields by a perturbation theory method on a Green function basis. Scattering of the charged particles Coulombian field. A Compton scattering on the charged particles**.**	6
5. Electroweak theory. Higgs's mechanism. Terms of a Lagrangian for U (1) and SU (2) of symmetries. Neutral charged currents. Problem of mass of particles. Spontaneous violation of a symmetry. Abelian mechanism of Higgs. Mass of vector bosons and fermions.	6

Learning outcomes and assessment

Learning outcomes	Assessment methods
nobility: *– the concept of interactions in the modern quantum field theory;* *– main approaches of research of hadrons structure and other partial particles;* *– the theoretical and experimental ideas which are developing into accelerating and not accelerating physics;*	Ability to solve corresponding problems
to be able: *– to analyze any process with participation of hadrons and leptons from the point of view of conservation laws of quantum numbers and C -, P-, T - parities;* *– to build and use charts of Feynman for calculation of section of interaction of hadrons and leptons;*	Ability to solve corresponding problems
to own: *– by the main methods of the theoretical and phenomenological description of hadron processes.*	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	34	-	-	+	+	-	+	4

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Course "Computer simulation"
(1-year/2-year master)
Faculty of Physics and IT

General data

Code	УД 36-2015-671/уч от 28.05.2015
Course title	Computer simulation
Course status in the programme	Compulsory
Course level	Master level
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	S.S. Girgel
Academic staff	S.S. Girgel
Volume of the course: parts and hours	34 academic hours
Language of instruction	RU
Possibility of distance learning	Planned
Abstract	The course deals with the study of computer mathematics packages, which allow performing analytical, numerical and graphical calculations with a specified degree of accuracy
Goals and objectives of the course in terms of competences and skills	Mastering the basics of theoretical knowledge and acquiring practical skills in computer simulation of physical processes and phenomena
Structure and tasks of independent studies	4 problems from main topics of the course within the framework of Students’ Individual Work (SIW) must be solved at home
Recommended literature	Manzon B.M. Maple V. Pover Edition. M. 1998.- 240 c. Wolfram S. Mathematica. Book Fourth Edition. Mathematica Version 4. Cambridge. 1470 p.
Course prerequisites	Fundamentals of general physics and mathematics
Courses acquired before	Mathematics

Course outline

Theme	Hours
Lectures	
Computer mathematics systems: history, modern possibilities and prospects The history of computer mathematics development. Modern analytical and numerical capabilities of computer mathematics.	2
Mathematica, its features, syntax and work with documents Mathematica and its symbolic, numerical and graphical capabilities. Mathematica system interface.	2
Analytical and numerical calculations in Mathematica system Computer algebra. Programming in the Mathematica environment.	2
Math extension package Kernel and Math extension package. Demo packages.	2
Graphical capabilities of Mathematica system Built-in 2d- and 3d-graphics. Directives and options for 2D and 3D graphics. Scaling	2
Modeling of physical processes in Mathematica system Drawing graphs with a lot of objects. Using additional options in Graphics package	2
Maple system and its capabilities Main characteristics of the system. Kernel and extension package. System User Interface	2
Maple Help System and its use Help access. Access to the examples directory. New Tutorials	2
Analytical and numerical calculations Symbolic computing. Analytical calculations. Working with mathematical expressions and functions.	2
Equations and differential equations solution in Maple system The main function “solve” for solving equations. The solution of common differential equations and partial differential equations	2
The use of the options and directives of 2D graphics in Maple system	2

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Restriction on axes. Lines styles, their coloring. Title and inscriptions along XY axes typing.	
The use of options and directives and 3d graphics in Maple system The number of cells modifying in the 3d graphics. The modifying of the perspective and review of the spatial figure.	2
The use of other extension package Student Package and its ideology. The solution of linear algebra and optimization systems.	2
Practical	
Graphics of “plots” extension package	2
The use of “plots” extension package for computer simulation of physical processes	2
The construction of physical fields	2
The use of Maple multimedia capabilities in the computer simulation of physical processes	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
Computer mathematics systems possibilities	Ability to solve corresponding problems
The visualization principles of physical phenomena using computer graphics	Ability to solve corresponding problems
Awareness of the fundamentals of analytical, graphical and numerical methods for physical processes simulation	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	Control of independent work
1.	+	-	26	-	8	-	+	-	+	6

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Course "Quantum theory of atomic and molecular spectrums" (for master students) Faculty of Physics and IT

General data

Code	
Course title	Quantum theory of atomic and molecular spectrums
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Physics”
Responsible instructor	N.V. Maksimenko
Academic staff	N.V. Maksimenko
Volume of the course: parts and hours	46 academic hours
Language of instruction	RU
Possibility of distance learning	Not planned
Abstract	The relevance of studying of this discipline is dictated by need of statement of a principal physics and theories of an atomic spectrum analysis which is widely used when developing new technologies of a research of materials in instrument making, mechanical engineering, electronic industry. Need of discipline is bound to application of spectral techniques in the solution of the new engineering tasks arising at a research of various physical phenomena. In statement of discipline a comprehensive approach on studying of the modern problems of an atomic spectrum analysis is used: from development of theoretical bases to the wording of practical recommendations about effective use of the gained knowledge.
Goals and objectives of the course in terms of competences and skills	The purpose of discipline is mastering undergraduates bases of an atomic spectrum analysis. Problems of discipline are: - acquaintance of undergraduates with the main methods of the quantum field theory in studying of energy distributions; - assimilation of elements of a perturbation theory; - formation of skills on use of algebra of operators of secondary quantization.
Structure and tasks of independent studies	For monitoring and self-checking of knowledge and abilities of students of this discipline it is used: - the solution of objectives with their protection, - examination.
Recommended literature	1. Haken, H. Kvantovopolevaya theory of a solid body / H. Haneken. – M.: Science, 1980. 2. New gardens, B.K. Methods of mathematical physics of molecular systems / B.K. Novosadov. – M.: URSS, 2010.
Course prerequisites	Optics of light bunches, Computer model operation
Courses acquired before	Optics, Quantum mechanics

Course outline

Theme	Hours
Lectures	
1. Definition of energy distributions of a one-dimensional oscillator by methods of the quantum field theory One-dimensional harmonic oscillator as quantum system. Quantum-mechanical oscillator: operators of the birth and destruction. Operator of Hamilton of a one-dimensional oscillator. A Schrodinger equation for stationary states of an oscillator. Permutation ratios. Chart of quantum levels and potential energy of a harmonic oscillator. Selection rules. An oscillator in power representation.	2

2. Energy distributions and quantum states of a set of untied oscillators The system N of the particles making small fluctuations independent from each other about equilibrium position. The operator of Hamilton for untied oscillators. Zero-point energy. Permutation ratios for bose-operators. Calculation of mean values by means of operators of the birth and destruction	2
3. Quantization of a scalar wave equation Quantization of a three-dimensional wave equation. Lagrange function. Lagrangian density. Equation of Lagrange. Three-dimensional Dirac delta function. Permutation ratios. Operator of Hamilton. Law of dispersion	2
4. Quantization of an electromagnetic field Maxwell's equations in vacuo. Gage transformations for vector and scalar potentials of an electromagnetic field. Coulomb calibration. A Lagrange function and Hamilton for components of vector potential. Initial interface. Permutation ratios for components of an impulse and amplitude of the field	2
5. Quantization of a Schrodinger equation within statistics to Bosa Secondary quantization. Schrodinger equation. Time factor. Permutation ratios for wave functions and for amplitudes of operators of the birth and destruction. Corpuscular character which provides quantization of the field. Bosons	2
6. Definition of conditions of atom of Hydrogenium Hydrogenium atom as the system consisting of the based core and the electron moving around it. The solution of a Schrodinger equation with a centrally symmetric potential. Main quantum number of n, l orbital quantum number. Degeneracy multiplicity of energy levels of atom of Hydrogenium. Designations of conditions of an electron with various values of quantum numbers of n and l. A probability density of finding of an electron apart from a core for various states	2
7. Energy distribution of atom of Hydrogenium Scheme of quantum levels of atom of Hydrogenium. Spectral terms. The transitions allowed by selection rules. Lyman, Balmer, Pashen, Breket, Pfundt's spectral series. Serial regularities. Resonance line of atom of Hydrogenium. Amendment, the bound to an electron spin. Fine structure. Lamb shift	2
Practical	
1. Definition of energy distributions of a one-dimensional oscillator by methods of the quantum field theory One-dimensional harmonic oscillator as quantum system. Quantum-mechanical oscillator: operators of the birth and destruction. Operator of Hamilton of a one-dimensional oscillator. A Schrodinger equation for stationary states of an oscillator. Permutation ratios. Chart of quantum levels and potential energy of a harmonic oscillator. Selection rules. An oscillator in power representation.	4
2. Energy distributions and quantum states of a set of untied oscillators The system N of the particles making small fluctuations independent from each other about equilibrium position. The operator of Hamilton for untied oscillators. Zero-point energy. Permutation ratios for bose-operators. Calculation of mean values by means of operators of the birth and destruction	2
3. Quantization of a scalar wave equation Quantization of a three-dimensional wave equation. Lagrange function. Lagrangian density. Equation of Lagrange. Three-dimensional Dirac delta function. Permutation ratios. Operator of Hamilton. Law of dispersion	4
4. Quantization of an electromagnetic field Maxwell's equations in vacuo. Gage transformations for vector and scalar potentials of an electromagnetic field. Coulomb calibration. A Lagrange function and Hamilton for components of vector potential. Initial interface. Permutation ratios for components of an impulse and amplitude of the field	4
5. Quantization of a Schrodinger equation within statistics to Bosa Secondary quantization. Schrodinger equation. Time factor. Permutation ratios for wave functions and for amplitudes of operators of the birth and destruction. Corpuscular character which provides quantization of the field. Bosons	4
6. Definition of conditions of atom of Hydrogenium Hydrogenium atom as the system consisting of the based core and the electron moving around it. The solution of a Schrodinger equation with a centrally symmetric potential. Main quantum number of n, l orbital quantum number. Degeneracy multiplicity of energy levels of atom of Hydrogenium. Designations of conditions of an electron with various values of quantum numbers of n and l. A probability density of finding of an electron apart from a core for various states	2
7. Energy distribution of atom of Hydrogenium Scheme of quantum levels of atom of Hydrogenium. Spectral terms. The transitions allowed by selection rules. Lyman, Balmer, Pashen, Breket, Pfundt's spectral series. Serial regularities. Resonance line of atom of Hydrogenium. Amendment, the bound to an electron spin. Fine structure. Lamb shift	2
8. Helium atom. Energy distributions of orthohelium and parahelium	4

Energy and function of state of atom of helium in a zero approximation of a perturbation theory. Hamiltonian of system of two electrons. A Schrodinger equation for nonperturbed system. Helium ionization potential. Quantum states. Couple - and orthostates. Selection rules for the systems of terms. Dependence of levels of energy on a cooperative spin of system. Spin-orbit interaction. Rules of the sums. Ultraviolet and infrared spectral ranges of helium	
9. Written test	2
CIW	
1. Helium atom. Energy distributions of orthohelium and parahelium Energy and function of state of atom of helium in a zero approximation of a perturbation theory. Hamiltonian of system of two electrons. A Schrodinger equation for nonperturbed system. Helium ionization potential. Quantum states. Couple - and orthostates. Selection rules for the systems of terms. Dependence of levels of energy on a cooperative spin of system. Spin-orbit interaction. Rules of the sums. Ultraviolet and infrared spectral ranges of helium	2
2. Exchange interactions in a quantum mechanics Electrostatic energy of two electric charges (electronic clouds), distributed in space. Transitions of electrons from one quantum state in another and back. Exchange integral. Exchange energy. An exchange interaction in the systems of identical particles	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
nobility: principles of quantization of a scalar wave equation and electromagnetic field; methods of secondary quantization for calculation of functional sizes; a substance of exchange approach in a quantum mechanics;	Ability to solve corresponding problems
to be able: to use the gained theoretical and practical knowledge, materials of reference books and express literature at the solution of applied problems of an atomic spectrum analysis; to use results of researches of atomic and molecular spectrums;	Ability to solve corresponding problems
has to own: by methods of the analysis of power conditions of hydrogen-like atoms; knowledge in definition range of dynamic variables of an electromagnetic field; skills of calculation of a range of energies of the indignant quantum system.	Ability to solve corresponding problems

Study subject structure

Part	Semester		Hours per semester			Tests				CIW
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	18	28	-	-	+	-	+	4

The head of GSU team

The manager of GSU team

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6. Belarusian State Technological University

6.1. Summary

To improve education in Physics, Applied Physics, Nanomaterials, Nanotechnologies and Photonics in Belarusian universities and to make it closer to Bologna system, BSTU has developed new Curricula for 1,5 year masterships by specialty 1-48 80 04 Technology and processing of polymers and composites and also renewed training programs for 1-year masterships (in the previous 5+1 system). The description of new Curricula was presented in the previous Activity Reports 1 and 2. These Curricula are divided on 3 parts (components): Preliminary State (mandatory) component, University component and Courses at students` option. Every Curricula includes titles of courses, values of hours and some other information (number of lectures, type of reporting, etc.). Validated versions of Curricula in Russian and English, study programs of the developed courses and didactic materials to them (synopsises, presentations, etc.) are presented in Appendixes 1 and 2.

6.2. Description of the courses / education programs

BSTU Master Course "Functional nanomaterials"

Faculty of Organic Substances Technology

General data

Code	
Course title	Functional nanomaterials
Course status in the programme	Elective course
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Processing of polymers and composites”
Responsible instructor	Vishnevski Konstantin
Academic staff	Vishnevski Konstantin Anna Egorova
Volume of the course: parts and hours	1 part, 54 academic hours
Language of instruction	RU

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Possibility of distance learning	Yes
Abstract	In the general case, the theory of nanocomposites predicts the achievement of significant results in improving the properties when the polymer matrix is filled with a small amount of a highly active nanodisperse component. Thus, the use of nanoscale additives introduced in small quantities in polymeric materials, which improve the technological and operational properties of products based on them, is a promising direction in creating new competitive products.
Goals and objectives of the course in terms of competences and skills	The main goal of the discipline is the study of modern functional nanomaterials and the possibility of their application to create a new generation of polymeric materials and products. The aim of the discipline is to familiarize oneself with the properties of nanomaterials and the methods of their research; to study the directions of development of nanotechnologies as a purposeful creation of nanomaterials, as well as the search and use of natural objects with nanostructured elements, the creation of finished products with the use of nanomaterials, and the integration of nanomaterials and nano-technologies into various branches of industry and science; to study modern means and methods for studying the structure and properties of nanomaterials, as well as methods for controlling and attesting products and semi-finished products for nanotechnologies.
Structure and tasks of independent studies	At home must be prepared 2 tests and written 1 essay from 7 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	Functional nanomaterials. https://dl.bsu.by/course/view.php?id=849
Course prerequisites	Fundamentals of general physics and mathematics, quantum mechanics, thermal dynamics.
Courses acquired before	Based on the knowledge received by students at the first stage of higher education in the study of disciplines "Technology of elastomeric compositions"; "Structure and properties of rubbers", "Fundamentals of the recipe building of elastomeric compositions", "Technology of composite materials", "Plastic mass technology", "Modification of polymeric materials and methods for their identification", "Fundamentals of the recipe building of paint and varnish materials", "Fundamentals of the recipe building of elastomeric materials", "Methods of research and modification of the properties of organic substances, materials and products "

Course outline

Theme	Hours
Lectures	
1. Introduction to the subject. The role of functional nanomaterials in modern materials.	4
2. Physics of Carbon Low-dimensional Systems and Device Structures. Carbon low-dimensional systems: from zero-dimensional to fractal. Model of fullerene formation in carbon arc discharge plasma. Triode on a single fullerene. Endofullerenes. Relay based on carbon nanotubes filled with magnetic endofullerenes. Single- and bilayer of graphene. Nanodynamometer and tunnel diode based on the two graphene layers separated by argon toms. Fractal carbon materials: applications in spintronics, photonics and mechatronics.	2
3. **Arrays of carbon nanostructures : fabrication, properties and applications** Methods of obtaining arrays of carbon nanotubes. Electrical properties of CNT arrays. Magnetotransport properties of CNT arrays. Instruments and sensors based on CNT	2
4. Conductive Polymers. 4.1. Structure, properties and classification of polymers. General concepts. Features of physical properties of polymers.	2

Semiconductor and conductive polymers. Fundamentals of Electrophysics of Polymers. Charges in the dielectric, dipoles and polarization. Dielectric losses. Electrical conductivity of polymers. Contact phenomena.	
4.2 Synthesis of semiconductor and electrically conductive polymers. Polymers with a system of conjugated bonds. Nanocomposites based on polymers. Molecular complexes with charge transfer. Ion-implanted polymers. The use of conductive polymers as functional nanomaterials	2
5. **Nanofibers: synthesis, properties and applications.** Methods for forming nanofibers. Methods for controlling viscosity and surface tension. Electroforming nanovolokon from solutions of polymers, the basis of the method of electroforming, the main technological parameters of the process, the properties of the molding solution and their effect on the process and morphology of the nanofibers obtained.	2
6. Elastomeric compositions with carbon nanomaterials. Features of the interaction of highly dispersed carbon additives with an elastomeric matrix of various nature and rubber compound components. The relationship between the structure, the dosage of nanoadditives and the properties of filled elastomeric compositions. Change in the structure of vulcanizates of filled elastomeric compositions based on butadiene-nitrile rubbers with the introduction of carbon nanomaterials.	2
7. **Paintwork materials modified with carbon nanoparticles.** Methods of introducing carbon nanomaterials in the form of suspensions in solvents. Effect of carbon nanomaterials on the physico-mechanical and protective properties of coatings based on modified alkyd and epoxy primers.	2
8. **Physicochemical regularities of the formation of one-component and nanocomposite coatings based on polymers from the active gas phase.** Morphological features of nucleation and growth of coatings, features of molecular structure and orientation effects in boundary layers. Influence of nanosecond laser radiation, plasma treatment of dispersion products on the molecular structure, morphology and properties of deposited thin-film systems.	2

Learning outcomes and assessment

Learning outcomes	Assessment methods
To evaluate the effect of functional nanomaterials, their chemical nature and concentration on the properties of modified polymer matrices and products based on them.	Ability to solve corresponding problems
To know how to introduce nanoscale materials into polymer matrices of different chemical nature	Ability to solve corresponding problems
To know the directions of nanotechnology development both in the creation of nanomaterials and in the search for possible branches of their application for creating a new generation of polymer materials and products	Ability to solve corresponding problems
To know the main types of functional nanomaterials, their structure, properties, methods of obtaining	Successfully worked out by performing home work
To the skills of using patent-information research on the development of methods for the production of paint and varnish materials and the production of coatings, to assess their novelty and technical level	Successfully worked out by performing home work
At home must be done 1 essay	Successfully written home essay

Study subject structure

	Semester	Hours per semester	Tests	

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Part	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	ECTS
1.	+	-	20	4	-	–	–	+	+	1

BSTU Master Course "Promising technologies for processing polymers and composites"

Faculty of Organic Substances Technology

General data

Code	
Course title	Promising technologies for processing polymers and composites
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Processing of polymers and composites”
Responsible instructor	Prokopchuk Nikolay, Vishnevski Konstantin
Academic staff	Prokopchuk Nikolay, Vishnevski Konstantin, Anna Egorova
Volume of the course: parts and hours	1 part, 108 academic hours
Language of instruction	RU
Possibility of distance learning	No
Abstract	At present, the demand for polymer and composite materials with high operational properties has increased. In a broad sense, the processing of polymers and composite materials on their basis can be considered as engineering activity associated with the transformation of raw materials into the required products. Most of the methods currently used in the technology of processing polymers and composite materials are modified analogs of the methods used in the ceramic and metalworking industries.
Goals and objectives of the course in terms of competences and skills	At the present time, many processes and methods have been developed, the main ones of which are mixing, calendering, casting, direct pressing, injection molding, extrusion, pneumoforming, thermoforming, foaming, reinforcement, melt molding and hard-phase molding, etc. Actual consideration of modern methods and methods for processing polymer and composite materials in products and coatings. The main goal of the discipline is to study promising methods of production and processing of polymer and composite materials. The task of the discipline is the mastering of the knowledge system by the technology of processing polymeric materials into various products; mastering the methods of creating composites based on polymers, their processing into products of various functional purposes.
Structure and tasks of independent studies	At home must be prepared 2 tests and written 4 essay from 16 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	Rubber Technology 2E: Compounding and Testing for Performance / by John S. Dick / ISBN-13: 978-1569904657. Structure and mechanical properties of polymers / Gul V.Ye., Kuleznev V.N. // Moskow : Himija,

	1994. – 367 c.
Course prerequisites	Chemistry and physics of polymers, Theoretical basis for processing polymers and composites, courses of special disciplines.
Courses acquired before	Based on the knowledge received by students at the first stage of higher education in the study of disciplines "Technology of elastomeric compositions"; "Structure and properties of rubbers", "Fundamentals of the recipe building of elastomeric compositions", "Technology of composite materials", "Plastic mass technology", "Modification of polymeric materials and methods for their identification", "Fundamentals of the recipe building of paint and varnish materials", "Fundamentals of the recipe building of elastomeric materials", "Methods of research and modification of the properties of organic substances, materials and products "

Course outline

Theme	Hours
Lectures	
1. Modern principles of preparation of rubber compounds. The theory of mixing. Features of the use of mineral fillers, the process of silanization. The design of modern mixing and refining equipment.	3
2. Technological process of manufacturing rubber products by injection molding. Theoretical aspects of the process of injection molding. Requirements for rubber compounds. Formation of molding and vulcanization regimes. Intensification of the process of injection molding.	1
3. The current state of procurement production and modern requirements for the final operations of the production of rubber products Manufacturing of blanks of rubber compounds. Preparation of reinforcing materials. Processing of rubber products after vulcanization.	2
4. Current trends in the use of mineral fillers in tire rubber formulations. The state of the problem. Features of the structure and properties of mineral fillers. Problems of combining mineral fillers with an elastomeric matrix of rubbers of general purpose.	2
5. The prospect of using nanomaterials in formulations of elastomeric compositions for the production of rubber products. Types and types of carbon nanomaterials. Features of the interaction of nanoadditives with an elastomeric matrix and ingredients of rubber compounds.	2
6. Modern principles for improving the formulation of rubber compounds. Use of ingredients of multifunctional action. Their influence on the plastoelastic and technical properties of elastomeric compositions.	2
7. Modern technologies for the production of foam products from plastics. The technology of production of profile products from LDPE by extrusion with physical foaming. Technology of manufacturing the material "penoplex" by the physical foaming of polystyrene	1
8. New technologies for the production of plastic pipes. Production of flexible pre-insulated pipes from PE-RT. Technology for the production of pipes from miscible polyolefins. Production of pre-insulated steel-polyethylene pipes.	1
9. Progressive technologies for the production of plastic products by injection molding. Obtaining products from thermoplastics by injection molding with gas and water. Manufacturing of products by injection molding	2

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by labeling and decorating in a mold. Technology of injection molding with pressing parts. New combined injection molding technology. Technology of casting of hybrid metal-polymer products. Technology of production of two-component plastic pallets by injection molding	
10. New technologies for the production of films and filaments. The technology of manufacturing very thin protective films. Production of bubble film. The technology of manufacturing a flat polypropylene film.	1
11. Special technologies of plastics processing. New technologies for welding plastics. The technology of production of intelligent fibrous polymer composite materials (IVPKM). The technology of making the material "Spondbond" and "SpondBel". Technologies "Doplhin", "Combimelt", "Tecomelt", "Foammelt". Technology of granulation of highly filled compositions.	2
12. Principles for the development of formulations for modern paint coatings for special purposes. The main parameters taken into account in the formulation of modern paint and varnish materials: two-pack epoxy and polyurethane, materials with a high dry residue, water-soluble and water-dispersive, etc. Selection features	1
13. Technological process of manufacturing of modern paint and varnish materials. The technology of manufacturing unpigmented paint and varnish compositions. The technology of manufacturing pigmented paint and varnish compositions.	1
14. Modern methods of obtaining paint and varnish coatings. Modern methods of applying paint and varnish materials of various chemical nature and the formation of coatings on their basis.	1
15. The prospect of using nanomaterials in the formulations of paint and varnish compositions to produce coatings with improved properties. Types and types of carbon nanomaterials and their properties. The methods of introducing nanoadditives into paint and varnish materials of various chemical nature. Features of the interaction of nanoadditives with a polymer matrix. Effect of nanoadditives on the value of the volume concentration of pigments and the properties of paint coatings.	1
16. The influence of new functional additives, fillers and other components on the technological properties of paint and varnish compositions and the physico-mechanical and protective properties of coatings based on them. Features of the selection of new functional additives (catalysts, accelerators, activators, hardeners, defoamers, thickeners, neutralizers, biocides, coalescents, deaerators, dispersants, preservatives, corrosion inhibitors, etc.) on the properties of paint and varnish compositions and coatings based on them. Influence of chemical nature and concentration of functional additives on the properties of paint and varnish compositions and coatings on their basis.	1

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know technological features of processing polymers depending on the physical form of the polymer and its chemical nature;	Ability to solve corresponding problems
To know interrelation of physico-mechanical characteristics of final polymer products depending on the choice of polymer processing method;	Ability to solve corresponding problems
To know hardware design of the technological process of polymer processing	Ability to solve corresponding problems
Be able to use the terminological apparatus of the course when presenting the choice of the polymer processing method;	Successfully worked out by performing home work
Be able to adequately implement the method of processing the polymer, depending on its chemical and physical structure.	Successfully worked out by performing home work
At home must be done at least 2 essays	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				ECTS
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	24	10	-	–	–	+	+	3

BSTU Master Course "Theoretical basis of polymer processing"

Faculty of Organic Substances Technology

General data

Code	
Course title	Theoretical basis of polymer processing
Course status in the programme	Compulsory
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Processing of polymers and composites”
Responsible instructor	Prokopchuk Nikolay. Shashok Zhanna
Academic staff	Prokopchuk Nikolay, Shashok Zhanna
Volume of the course: parts and hours	1 part, 140 academic hours
Language of instruction	RU
Possibility of distance learning	No
Abstract	When mastering the discipline, undergraduates use the knowledge gained during their studies at the first stage of higher education: in the study of engineering graphics, applied mechanics, general chemical technology, processes and devices of chemical technology, physics and chemistry and technology for obtaining polymers, materials science.
Goals and objectives of the course in terms of competences and skills	The purpose of the discipline: the consolidation of students in basic knowledge in the field of technology and equipment for the production of products made of polymers and polymer composites. Goals of the discipline: - consolidation of fundamental knowledge in the field of technology for processing polymeric materials; - consolidation of modern theoretical knowledge and practical experience in the field of working principles and designs of the main equipment used in the technology of processing polymeric materials; - consolidation of practical skills in studying the technological and operational properties of polymer materials, assessing the quality of products from them.

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Structure and tasks of independent studies	At home must be prepared 4 tests and written 2 essay from 9 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	Kireev V.V. High-molecular compounds. - Moscow: Chemistry, 1992. - 512 p. Volodin V.P. Extrusion of profile products from thermoplastics. - St. Petersburg: Profession, 2005. - 480 p.
Course prerequisites	Chemistry and physics of polymers, Theoretical basis for processing polymers and composites, courses of special disciplines.
Courses acquired before	Based on the knowledge received by students at the first stage of higher education in the study of disciplines "Technology of elastomeric compositions"; "Structure and properties of rubbers", "Fundamentals of the recipe building of elastomeric compositions", "Technology of composite materials", "Plastic mass technology", "Modification of polymeric materials and methods for their identification", "Fundamentals of the recipe building of paint and varnish materials", "Fundamentals of the recipe building of elastomeric materials", "Methods of research and modification of the properties of organic substances, materials and products "

Course outline

Theme	Hours
Lectures	
1. Theoretical foundations of the technology of synthesis of polymer materials.	4
1.1 Methods for the synthesis of polymers and elastomers in melt, in solution, in emulsion and in suspension. Effect of preparation methods on the structure and properties of polymers.	2
1.2 Molecular structure and macroscopic properties of rubbers and plastics. Molecular weight, molecular weight distribution. Aggregate and phase state of polymers. Structuring of polymers, types of nets and their parameters	2
2. Physicomechanical properties of plastics and elastomers and methods for their evaluation.	4
2.1The main technological and rheological properties of polymers that determine their processing into products. Interrelation of polymer structure and technological properties of polymers. Test methods for plastics, rubbers and rubber compounds and vulcanizates. Strength and deformation properties of polymers.	2
2.2 Factors affecting the strength of polymers. Dependence of strain on stress. Relaxation properties. Durability and fatigue endurance. Temperature dependence of the basic properties of polymers.	1
2.3 Aging and stabilization of polymers. The mechanism of action of the basic stabilizer classes	1
3. Theoretical basis of polymer processing	4
3.1 Technological methods used in the processing of polymers. The mechanism of structure formation in the processing processes.	2
3.2 Theoretical basis of surface phenomena of polymeric materials. Physico-chemical basis of polymer processing. Rheological properties of thermoplastics, thermosets and rubber	2
4. Thermoplastics and thermosets. Natural and synthetic rubbers.	6
4.1 Polypropylene, block polystyrene, polyvinyl chloride, polymers and copolymers based on acrylic and methacrylic acids.	2
4.2 Polyurethanes and polyurethane foams, phenol-formaldehyde oligomers, polyethylene terephthalate, polybutylene terephthalate, epoxy resins.	2
4.3 Natural rubbers, thermoplastic elastomers.	2

5. Ingredients of polymer composite materials. 5.1 General requirements for ingredients, quality assessment. Classification of ingredients. Curing. Change of properties of rubbers during vulcanization. Aging of polymers. 5.2 Filling and filling. Reinforcing materials. Softeners, softeners.	4 2 2
6. Technology of processing of plastics and composite materials. 6.1 Mixing of polymers, their compatibility. Basics of the theory of adhesion, bonding and impregnation of materials. Extrusion of thermoplastics. 6.2 Production of films. Manufacture of pipes. The essence of the process of injection molding. 6.3 Pressing thermoset materials. Molding of thermosetting plastics. Forming of products from composite materials.	4 2 1 1
7. The main processes of rubber production. 7.1 Methods for the evaporation, cutting and granulation of rubbers. Plasticity of rubbers. Molding of rubber compounds. Calendering process. Syringing. Molding of rubber compounds under pressure 7.2 Methods of attaching rubber to metal products. Vulcanization of rubber products. Methods of vulcanization. Rubber as a structural material	4 2 2
8. Technology of composite materials. 8.1 Polymeric materials based on curable oligomers. Crosslinking of thermoplastic polymeric materials. Plasticizers. Mixing of polymers. 8.2 Classification of gas-filled polymer materials. Classification of fillers used in the production of polymer composite materials. Fibrous fillers. 8.3 Fillers for thermoplastics. Filled thermoplastics.	4 2 1 1
9. The main processes for obtaining paint and varnish coatings. 9.1 General information on paintwork materials and coating technologies based on them. 9.2 Interaction of paintwork materials with a solid surface 9.3 Methods of application of paints and varnishes 9.4 Methods of curing paint and varnish coatings. 9.5 Physicomechanical and protective properties of paint and varnish coatings	6 1 1 2 1 1

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know modern achievements in the field of chemistry and physics of high-molecular compounds, polymeric materials science;	Successfully worked out by performing home work
To know modern methods of theoretical and experimental research in various sections of chemistry, methods for determining the composition, structure of matter, the mechanism of chemical processes, their theoretical theories and the possibilities and limits of applicability;	Ability to solve corresponding problems
To know the structure and principles of the functioning of computer systems for automation of scientific research (ASNI), automated design (CAD), automatic control (ACS), algorithms and criteria for optimality used in them, methods for optimizing chemical production, and be able to	Ability to solve corresponding problems

apply optimization methods and algorithms, as well as corresponding software packages to optimize the research, design and management of chemical production	
Be able to determine the main characteristics of processes involving the solid phase, use mathematical models of processes, determine the parameters of processes in industrial devices with the participation of the solid phase;	Ability to solve corresponding problems
Be able to choose a research method for a given scientific and theoretical problem, plan and conduct an experimental study, interpret the results of the study.	Ability to solve corresponding problems
At home must be done at least 2 essays	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				ECTS
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	-	+	42	10	-	–	+	+	+	4

BSTU Master Course "Modification of polymers and composites"

Faculty of Organic Substances Technology

General data

Code	
Course title	Modification of polymers and composites
Course status in the programme	Elective course
Course level	Master Studies
Course type	Academic
Field of study	Specialty “Processing of polymers and composites”
Responsible instructor	Shashok Zhanna, Sabadaha Elena, Vishnevski Konstantin
Academic staff	Shashok Zhanna, Sabadaha Elena, Vishnevski Konstantin, Anna Egorova
Volume of the course: parts and hours	1 part, 54 academic hours
Language of instruction	RU
Possibility of distance learning	No
Abstract	Modification is one of the most accessible ways to improve the properties of polymers and composites, because allows to synthesize polymer products with specified properties without a significant change in the technology of their production.
Goals and objectives of the course in terms of competences and skills	The main goal of the discipline is to obtain master's knowledge, which consists in mastering the methods of modification of polymeric and composite materials and products based on them. The task of the discipline is to study the methods of chemical and physical modification of the main

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	methods, techniques, methods of modification of polymer and composite materials and products based on them in order to improve their technological and operational performance. The discipline program is developed taking into account the latest achievements of technology and the science of processing polymers and composites.
Structure and tasks of independent studies	At home must be prepared 5 tests and written 1 essay from 6 main parts of the course within the framework of Controlled Independent Work (CIW) of students
Recommended literature	1. Prokopchuk, N.R. Modification of properties of elastomeric compositions / N.R. Prokopchuk, Zh.S. Shashok, A.V. Kasperovich, I.S. Tashlykov. - Minsk: BSTU, 2012. - 217 with. 2. Nazarov, V.G. Surface modification of polymers / V.G. Nazarov. - Moscow: MSUP, 2008. - 471 p.
Course prerequisites	Chemistry and physics of polymers, Theoretical basis for processing polymers and composites, courses of special disciplines.
Courses acquired before	Based on the knowledge received by students at the first stage of higher education in the study of disciplines "Technology of elastomeric compositions"; "Structure and properties of rubbers", "Fundamentals of the recipe building of elastomeric compositions", "Technology of composite materials", "Plastic mass technology", "Modification of polymeric materials and methods for their identification", "Fundamentals of the recipe building of paint and varnish materials", "Fundamentals of the recipe building of elastomeric materials", "Methods of research and modification of the properties of organic substances, materials and products "

Course outline

Theme	Hours
Lectures	
Introduction to the subject. Analysis of trends in the development of fundamental works and technologies for the production of new polymer and composite materials, including nanoscale, with an improved set of performance indicators.	2
1. Classification of polymer modification methods. The main methods of chemical, physical and combined modification of polymers. Justification of the choice of the modification method. Chemical transformations of polymers. The main types of modifiers and their effect on the polymer	2
2. Chemical modification of polymeric materials in bulk and on the surface 2.1 Theoretical ideas about the chemical modification of polymers. Methods of chemical modification: mutual activation of components; oligomers; polymerization-capable compounds; low-molecular compounds. Formation of adhesion systems at the interface "polymer-reinforcing material" in the presence of modifiers 2.2 Operational properties of modified systems	4 2 2
3. Physical modification of polymeric materials in bulk and on the surface. Theoretical views on the physical modification of polymers. Modes of physical modification: thermal, irradiation, filling, mixing, plasticization. Technical properties of modified products..	2
4. Surface modification of polymeric products and reinforcing materials. Modification of the surface of polymer and composite products: plasma-chemical, ion implantation, ion-assisted coating, treatment with high-frequency glow discharge, halogenation, accelerated electrons, metallization and others. Structure and properties of the	2

modified surface. Properties of surface-modified polymers and products based on them.	
5. Modification of the ingredients of polymer mixtures. Features of the interaction of highly dispersed carbon additives with an elastomeric matrix of various nature and rubber compound components. The relationship between the structure, the dosage of nanoadditives and the properties of filled elastomeric compositions. Change in the structure of vulcanizates of filled elastomeric compositions based on butadiene-nitrile rubbers with the introduction of carbon nanomaterials.	4
6. Modification of secondary polymers. Modification of secondary polymers: chemical, mechanochemical. Effect of modification of the secondary polymer on the most important performance indicators of products for various purposes. Areas of use.	4

Learning outcomes and assessment

Learning outcomes	Assessment methods
To know the purposes and possibilities of modification of polymeric and composite materials and products on their basis.	Successfully worked out by performing home work
To know functional additives, properties of modified compositions, the main properties of modified polymeric and composite materials and products based on them and the field of their application;	Successfully worked out by performing home work
Be able to regulate the operational properties of products;	Ability to solve corresponding problems
Be able to apply the theoretical foundations of the discipline to solve specific practical problems	Ability to solve corresponding problems
Be able to experimentally determine the properties of polymer and composite materials and their compliance with the requirements of standards, as well as the properties of products	Ability to solve corresponding problems
At home must be done 1 essay	Successfully written home essay

Study subject structure

Part	Semester		Hours per semester			Tests				ECTS
	Autumn	Spring	Lectures	Practical	Lab.	Short test	Written test	Essay	Exam	
1.	+	-	20	4	-	–	–	+	+	1

6.3. Teaching/didactic materials uploaded to e-Library, virtual laboratory for student training, the instruction for its on-line usage

During the project implementation BSTU team has developed the following presentations for lecture courses:

5. **Functional nanomaterials** (lecture notes for specialty 1-48 80 04)

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These didactic materials are uploaded to the Moodle platform of BSU by the following Internet-adresses: https://dl.bsu.by/mod/folder/view.php?id=30904.