Guidance to Masters' Degree Programs in English at ETU "LETI"

Content:

1. Computer Science and Knowledge Discovery

The program offers students profound training in the fields of mathematical modelling, data processing and analysis, and software development. We also focus our subjects on the most recent trends in artificial intelligence and machine learning, signal and image processing, parallel and distributed computing, intelligent and embedded systems, pattern recognition and biometric technologies. The structure of the program consists of advanced professional studies, elective courses and Master's Thesis.

Graduates of the master's program will acquire professional skills for designing software and hardware, distributed systems, and applying computer tools for educational purposes. Graduates will acquire knowledge in information security, data mining algorithms and standards, system theory, data and visual analytics. The program is also accompanied by economic and humanitarian disciplines for broad education in English and successful future career.

Discipline	Credits	Description
Biometric Technologies	**3 ECTS**	The course is aimed at studying biometric dynamic and static characteristics of humans. We consider all stages of image processing in biometric problems: data acquisition, face image preprocessing, feature extraction from images. We draw special attention to efficient algorithms of reducing feature space dimension using features oriented to image processing as two-dimensional data. The course also involves algorithm implementation using vector-matrix techniques in MATLAB. We discuss the main principles of constructing, simulating, and testing human recognition systems based on face images. Various simulation models are also widely discussed.
Information Security	**4 ECTS**	The course includes all issues of determining, reaching, and supporting confidentiality as well as the following properties of information or its processing tools: integrity, availability, non-repudiation, accountability, authenticity, and reliability. The discipline helps students to master the main concepts and problems of information security and offers a number of important modern techniques of information security. The course is aimed at forming skills for working with existing products and developing information security software.
Advanced Data Analysis and Machine Learning		The course provides deep training in the field of big data analysis and extracting knowledge from raw data. We handle various machine learning tasks: classification, cluster-analysis, mining association rules, data visualization. Students will also acquire skills of using different data analysis tools including distributed data analysis: RapidMiner, Weka, R, Apache Spark.
Parallel Computing	**4 ECTS**	Students acquire new knowledge for a possible career in the field of parallel programming. We provide principles for constructing parallel computational systems and consider mathematical models of parallel algorithms and programs for analyzing the efficiency of parallel computing. The course considers low-level possibilities of modern operating systems for providing parallelism.

Advanced Mathematical Methods	**4 ECTS**	The course consists of selected topics from linear and multilinear algebra and numerical linear algebra that are important for applications in different branches of mathematics and physics, primarily in vector analysis, differential geometry, and numerical methods of ordinary and partial differential equations. Besides we discuss some natural applications of linear algebra such as recurrence relation and linear differential equations with constant coefficients.
Mathematical Modelling of Linear and Non-linear Systems	**4 ECTS**	The discipline familiarizes students with the basics of mathematical modeling and synthesis of linear and non-linear systems at the input/output mapping. We study different forms of models classified as multidimensional polynomials, regression models, and neural networks. The comparative analysis of mathematical models is performed. The discipline also covers methods and algorithms of model design by solving the problems of system operator approximation in the root mean square metric using the input and output signal sets. Various neural network synthesis in MATLAB is represented. Modeling and synthesis of nonlinear transformers, filters, and compensators are represented. The discipline is also aimed at studying nonlinear behavior of dynamical systems. It discovers the main properties of nonlinear processes during the design and use of a complex technical system. The discipline considers nonlinear dynamics and modern tools of dynamical analysis given through graphical programming environments. Students study mathematical representation of nonlinear systems and processes and their computer simulation through numerical integration.
Computer Tools in Education	**3 ECTS**	The discipline is devoted to studying software packages for numerical and symbol computing. We consider three different packages: numerical computations are represented in GNU Octave and R, symbol computations are represented in SageMath. All packages are distributed free of charge and are available for downloading. Special attention is paid to data types in embedded programming languages and visualization techniques, i.e. plotting graphs and diagrams.
Algorithmic Mathematics	**3 ECTS**	Algorithmic mathematics (computer algebra, symbolic or algebraic computations) deals with algorithms and software for handling mathematical expressions and other mathematical objects. This course familiarizes students with basic polynomial methods and algorithms over infinite and finite fields, Groebner bases, and algebraic varieties. The course allows students to get acquainted with theoretical fundamentals of basic methods and algorithms of polynomial factorization including Berlekamp's algorithm, algorithms for solving polynomial equations including those based on Groebner bases and Buchberger's algorithm.

Data and Visual Analytics	**4 ECTS**	Visual analytics is an advanced form of data analysis where analytical reasoning is followed by adoption of the highly interactive visualization techniques. This course introduces students to the concepts and tasks of visual analytics and examines several important data analysis and visualization techniques. It provides hands-on experience with both existing products and in the development of custom visual analytics software.
Basics of System Theory	**4 ECTS**	The discipline is oriented to mastering a number of areas of mathematics and system analysis used in engineering applications and academic research. The course encompasses all stages of complex system design beginning with information transform to digital form and its statistical processing and ending with system model design and its parameter optimization.
Languages for Hardware Design and Verification	**4 ECTS**	The discipline is aimed at studying tools for joint representation and debugging of software-hardware systems using SystemVerilog including special data types, object-oriented programming and quasi-stochastic representation of such systems.
Intelligent Systems	**3 ECTS**	The discipline provides a study of the basics of designing intelligent agents including movement, obstacle avoidance and pathfinding to tactical analysis and decision-making. The discipline also covers the use of algorithms based on decision trees, state machines, and elements of fuzzy logic. We consider applications of decision-tree training methods, the simplest neural networks and implementation of reinforcement training. The discipline also includes fundamentals of multiagent systems, specifics of designing intelligent agent environment, knowledge management, and natural language processing. This course discusses applications of the algorithms in a virtual environment (video game).
Distributed Systems and Technologies	**3 ECTS**	The discipline studies a wide range of issues connected with the main principles, concepts, and technologies of distributed systems: connection, processes, identity, synchronization, integrity, and replication, fault protection, and security. The knowledge provided by this discipline can be used for constructing and managing distributed systems. The discipline includes practical training classes. Unsupervised work of students suggests studying the recommended sources of literature and preparation for classes. The final certification is based on graded examination results.
Digital Signal Processing	**3 ECTS**	The course includes basic methods and algorithms of digital signal processing using computer simulation in MATLAB. The discipline includes discrete signals and their transforms, linear discrete systems and their characteristics, discrete Fourier transform (DFT) and its applications, design and analysis of FIR and IIR filters, quantization effects in digital systems, spectral analysis of signals, multirate signal processing, adaptive filters, wavelet transform. The course familiarizes students with theoretical fundamentals of basic methods and algorithms of digital signal processing, the technology of computer simulation of these methods and algorithms in MATLAB. The discipline helps to study embedded software packages (FDATool, FVTool, SPTool, WAVETool).

Computational Systems	**5 ECTS**	The discipline is devoted to the techniques and tools of parallel and distributed academic research using modern software and hardware tools. Students also acquire skills of working with high-performance computational systems.
Commercialization of Academic Results and Developments	**2 ECTS**	Commercialization of academic research results and developments is the process of their involvement in economic (commercial) use in different segments of national and global markets. In this situation we need to perform project evaluation and substantiation of economic efficiency of projects oriented to the production of high-technology production and advancement of new technologies.
Mathematical Foundations of Computer Science	**3 ECTS**	This discipline can be viewed as a continuation of the disciplines "Discrete mathematics" and "Mathematical logic and algorithm theory". The purpose of the discipline is to advance mathematical background of students, master the main models and techniques of computer mathematics. The discipline consists of the following parts: basics of universal algebra, discrete analysis, discrete functional schemes, applied logic, proof theory.
Algorithm Design and Optimization	**2 ECTS**	The discipline can be viewed as a relative of the discipline "Mathematical foundations of computer science" and it is an integral part of education in the field of computer science and information technologies. The purpose of the discipline is to advance the mathematical background of students and master the main techniques of designing, analysis, and optimization of algorithms. The discipline consists of the following parts: methods and strategies of algorithm design, algorithm complexity, sort algorithms and search algorithms, numerical algorithms, graph algorithms, general complexity theory of algorithms.
Software Development Technology	**5 ECTS**	The discipline provides knowledge and skill acquisition in the field of modern technologies of group development of software. We consider different models of the life cycle of software development, their advantages and drawbacks, capability maturity model-integrated (CMMI) and its key areas, team software process (TSP) and personal software process (PSP) developed in SEI University. We provide an overview of modern standards, methodologies, and documented processes and development environments: Rational Unified Process (RUP), Microsoft Solutions Framework (MSF), and TeamFoundation Server (TFS), agile development methodologies. We consider the issues of designing a project process, distribution of project roles, work planning and work tracking, quality monitoring and risk management.
Information Technologies in Academic Research and Project Activity	**3 ECTS**	The discipline is oriented to acquiring skills of applying high-performance computer engineering and information technologies for academic research and practical tasks from different knowledge domains. Students should be able to master new software packages and technologies for computational systems with different architecture, perform analysis of information technologies and select those that are the most efficient for handling practical and academic tasks formulated within the scope of industrial and/or pre-graduation practice. These tasks can be used for research and graduation project.

2. RF, Microwave and Terahertz Engineering of Wireless Systems

The program is to train students who will manage successfully professional activity in a globally competitive environment in such an interdisciplinary field as design and technology of the state-of-the-art high-frequency, microwave, and terahertz devices for communications, radar, and other wireless applications.

Discipline	Credits	Description
Introduction to Wireless Systems	**5 ECTS**	Studying the course, students learn physical foundations and design principles of wireless systems for data and energy transmission, gain an impression on main types of such systems, their evolution, applications, and future trends.
Computational Electromagnetics	**5 ECTS**	Discipline involves the study of physical bases and principles of numerical modeling of various microwave devices and antennas using finite-difference methods in the time and frequency domain, method of moments for wire and plane-layered structures, as well as using the mode-matching applied to the waveguide structures. Various forms of writing boundary conditions for boundary problems of electrodynamics, algorithms for generating vector electric and magnetic fields values by the Lorentz potentials are considered.
Foundations of Microwave Circuit Technologies	**5 ECTS**	The main features of micro- and nanostructured materials used in radio electronics are studied on the basis of modern concepts of nanophysics and nanochemistry. The main technological processes of the formation of micro- and nanostructures, modern and promising control and measurement technologies, methods for quantitative and qualitative analysis of nanoscale structures are considered.
Basics of Antenna Design	**5 ECTS**	In the course, the classification of antennas is given, their main characteristics are considered: the radiation pattern (RP), the width of the RP, the far and near antenna zones, the antenna input impedance, the directivity factor, the radiation resistance, the bandwidth, the gain factor, the efficiency. The basic types of antennas are considered: dipole, monopole, loop and printed antennas. The concept of phased array antennas (PhAA) is given. The lectures use the latest advances in the development and application of antennas in the field of wireless microwave systems. The practical study is aimed to obtain basic skills in the design of antennas for communication systems.
Passive Microwave Components and Device	**5 ECTS**	Studying the course is intended to familiarize students with microwave integrated circuit components, design principles and applications of passive microwave devices. Besides, it allows students to master basic practical skills in the design of microwave integrated circuits.

Computer Technologies of End-to-End Design	**5 ECTS**	The subject "Computer Technologies of End-to-end PCB Design" includes methods and techniques to design radioelectronic functional units based on modern information technologies of the end-to-end design as well as CAD/CAM complexes using these methods and technologies.
Wireless Communication Systems	**5 ECTS**	The basic principles of mobile communication systems, the features of the radio channel and the resulting limitations on the characteristics of wireless communication systems, estimation of the radio link budget, the features of propagation of radio waves on typical transmission paths, the structure and basic characteristics of mobile communication systems are considered.
Infocommunication Networks	**5 ECTS**	On the basis of a tiered approach to the construction of open systems, the following is considered: seven-layer Open Systems Interconnection model, especially the physical realization of network communication, transmission and reception of data by means of the data link layer, local area network, the network layer as a means of building a large network, wireless network technology. In the course, the following is studied: the functional layers of the communication process; functional-functional means of establishing, maintaining and disconnecting physical connections; the physical layer; data transfer protocols; routing and retransmission, multiplexing network connection, segmentation and consolidation; methods of transmission is given on the communication lines; typical network topology; communication devices; structure of local networking standards; switching methods; implementation of interworking; domain name system; WANs.
Active Microwave Devices	**6 ECTS**	The course "Active Microwave Device" is focused on the basics of designing active devices such as microwave low-noise amplifiers, power amplifiers, and oscillators. Also, attention is paid to active elements and technologies providing improved performance, mass production and miniaturization of the devices. Practical study is aimed at obtaining elementary skills in designing devices used in receiver and transmitter microwave modules of communication systems.CAD of Microwave Devices and Systems
CAD of Microwave Devices and Systems	**6 ECTS**	The course is devoted to the modern of computer-aided of microwave devices and system. The important aspects of building receiver and transmitter models as the system level are considered. A special attention is paid at the design of microwave devices such as low noise amplifiers, oscillators, mixers, filters, antennas etc.Th ebasic principles of designing microwave devices on microstrip transmission lines, which are suitable for computer-aided manufacturing by means of the printed circuit board and hybrid integrated circuit technologies, are studied. Design of filters, diplexers and power dividers is considered. While studying the course, the students learn consequentially the full cycle of electronic device design and realization from the target specification to release for production.

Microwave and THz Metamaterials	**6 ECTS**	In the course, students study the main properties of metamaterials (artificial electromagnetic structures) designed for practical applications in microwave and THz frequency range. The most important properties of metamaterials due to their lefthandedness are used for a design of microwave devices with improved performance and enlarged functionality. The following devices are under considerations: resonators and filters based on a combination of transmission lines with negative and positive dispersion, high impedance surfaces, multi-band passive devices, tunable devices, photonic band-gap metamaterials. The practical study focuses on obtaining basic skills for designing devices that are used in receiving modules of communication systems: miniature passive microwave devices, screening structures, printed antennas etc.
Introduction to Microwave Measurements	**4 ECTS**	When studying the course, students learn about methods to measure main characteristics of passive and active microwave devices as well as antennas. They master skills of practical work with the state-of-the-art measurement equipment. The course comprises basics of power measurement, scattering parameters and noise figure measurements of microwave devices as well as measurement of antenna characteristics, signal spectrum analysis and measurement of the dielectric material parameters at microwaves.

3. Laser Technologies

Students get knowledge of quantum electronics and laser techniques. They get skills of practical work with modern laser techniques and laser measurement equipment, the ability to carry out science research during the development of new laser measuring devices and systems.

Discipline	Credits	Description
Fundamental Courses		
Wave Optics	**6 ECTS**	Physical basics of optical systems for data collection, storage, and transfer are presented. Primary attention is paid to the laws of light reflection, refraction, and propagation in anisotropic media. Light propagation in optical fiber and the idea of the optical fiber communication systems are described on this basis. Light interference, as well as some of its applications (interference measurement converters, interference filters, and demultiplexers), are considered. The idea of moving media optics and measurement converters on this basis is presented.
Optical Systems and Components	**5 ECTS**	Contains the basic data on the principles of design, calculation, working out and adjustment of various optical systems. The basic types of imaging optical systems (telescopes, microscopes, camera lenses etc.), their features and the general properties are considered. Basics of the theory of the optical image and aberrations are presented. The basic types of non-imaging optical systems – lighters, projectors, various types of interferometers are considered also, and also the basics of optical photometry are considered. The course also presents the basics of optical materials and technology, including the processes of glass fabrication and optical crystals growth, the idea of glass and crystal processing (cutting, grinding, polishing and finishing). Main types of optical components (plates, prisms, wedges, spherical and aspherical lenses) are described. The information about optical films and coatings is presented. Finally, the idea of optical design, production and testing routines is presented.
Laser Technique	**5 ECTS**	The fundamentals of quantum electronics and laser technique are presented, including the fundamental laws of light emission and absorption, the idea of the inversed (active) media and of the light amplification. Basic principles of laser cavities and their modes are outlined. Basic principles of laser generation are described in semiclassical approximation. Laser technique fundamentals are illustrated by the more detailed description of various specific kinds of lasers, including gas lasers (neutral atom, ion, molecular and excimer ones), solid-state lasers (glass and crystalline ones, including the Q-switched lasers and lasers with mode synchronization) and semiconductor ones.
Laser Systems	**4 ECTS**	Course “Laser system” contains information about physical fundamentals and design of modern laser systems. Requirements to laser systems, used in science and industry, are analyzed. Main characteristics and technical features of laser systems are presented. Applications of laser systems in industry, environmental monitoring, optical communication and biomedicine are discussed.

Laser Radiation Control	**4 ECTS**	The course presents the physical background of the devices, providing laser beam control and transformation. We consider the light polarization rotation and the basics of nonreciprocal devices on their basis; the nonlinear optical methods and devices for radiation frequency conversion. The course also presents the information about the light scattering, including the stimulated one and about the wave front transformation and correction by means of adaptive optics and holography.
Optoelectronics	**4 ECTS**	The course provides the theoretical background of the passive optoelectronic devices. We consider the main components of such devices like light sources and sensors, the basics of photometry, the photo receivers'' performance as well as the basics of evaluation of signal and noise amplitudes at the photo receiver output. Special attention is paid to the practical implementation of the theoretical information.
Basic Special Disciplines		
Laser Measuring Systems	**4 ECTS**	The course is devoted to the physical background and principles of design of the laser measuring systems for evaluation of movement parameters like linear and angular movement, speed and acceleration. We consider the schemes and performance principles of modern laser measurement systems. Special attention is paid to the accuracy of such systems and to their efficiency improvement. The tendencies of technique development are considered.
Laser and Fiber Optic Technologies in Navigation Systems	**3 ECTS**	The subject of the course is the study of fundamentals and main types of optical gyros, based upon the use of quantum electronics and waveguide technologies – namely, of laser and fiber optical gyros, as well as of the systems, providing technique implementation in the measuring apparatus, in the inertial navigation and movement control systems.
Fiber and Integrated Optics	**4 ECTS**	Basic information about the principles of light propagation through optical fibers and waveguides is presented. Inter-modal and material dispersions in fibers are analyzed as well as their influence onto the rate of data transfer via fiber-optical communication lines (FOCL). Waveguide connectors, including the grating and prism type ones, are described. Two-channel directed splitters and other elements of integrated optics are considered as well as their use in FOCL. The means and methods of time and spectral multiplexing are analyzed. The course describes modern schemes of FOCL architecture. Diode light sources for FOCL applications are discussed and in addition, the fiber-optical sensors of various nature.

4. Renewable Solar Energy

The main characteristic of human activity at the beginning of the XXI century is a rapid growth of energy consumption. As one of the most promising environment-friendly renewable energy sources should be recognized solar energy which provides direct conversion of the solar energy into electrical energy. Over the past 20-30 years, the average growth rate of solar power engineering has been of about 30%. Such an intensive growth is due both to production expansion and to development of new structures and working principles of photoelectric converters.

Master's degree program «**Renewable Solar Energy»** is focused on current achievements in the field of renewable energy sources and photovoltaics. Students get knowledge of underlying physical principles and material science aspects of photovoltaics, technology and metrology of solar modules, equipment, design and maintenance of solar power plants. Special attention is dedicated to silicon photovoltaics, including the most efficient HIT structures. Students have access to the most modern and sophisticated technological and metrological equipment, carry out scientific research and get skills of practical work with real metrological instruments and technological apparatuses.

Discipline	Credits	Description
Renewable Energy Sources	**5 ECTS**	The course is one of the basic courses of the Master's degree program. Course considers questions of physics and technologies of solar modules. Course «Renewable energy sources» includes the study of the physical foundations of photovoltaic solar energy converters, characteristics of the materials used for their production, principles of modeling of solar cells, advanced production technologies aimed at improving the efficiency of solar energy converters.
Solar Energy Materials	**4 ECTS**	The course includes main branches of Condensed Matter Physics and Solid State Optics. The main points of the theory of electronic spectra of solids are discussed, along with the basics of the theory of radiation interaction with matter. The light absorption and other physical phenomena which determine the optical properties of crystalline and disordered semiconductors are considered. Special attention is paid to physical interpretation of studied phenomena, theoretical description and the most important experimental facts.
Micro- and Nanotechnology Processes	**4 ECTS**	The course considers materials deposition, etching and modifying methods at micro- and nanolevel which used in solid state electronics and integrated circuit components forming. Base processes and equipment used in conventional microtechnology and specific processes, permissive to form structures on molecular level and based on selforganization, selectivity, anisotropy abilities and matrices principle are studied.

Optics and Optical Measurements in Solar Energy	**3 ECTS**	The course covers basic optical and spectroscopic methods, techniques and equipment such as light photometry, UV/V spectrometry, Fourier transform infrared spectrometry, Raman spectroscopy, ellipsometry and interferometry, which are widely used in the diagnostics of materials and thin film structures of solar photovoltaics. The course also includes an introductory part dedicated to the fundamentals of geometrical and wave optics, laboratory workshops and seminars.
Diagnostics of Solar Energy Materials and Structures	**5 ECTS**	The course is devoted to modern techniques and methods of diagnostics and characterization of materials and structures in microelectronics and photovoltaics. The main techniques used within the microelectronics and photovoltaics are explained. In particular, the subject is focused on the most widely used techniques such as charge-based and probe methods, as well as chemical and physical methods.
Metrology of Solar Cells and Modules	**3 ECTS**	The course considers the following subjects: «Sunlight, its characteristics» where the sunlight characteristics and methods of indoor light parameters modeling, also a quality monitoring of parameters of sunlight will be considered. «Reference solar cells and their design». The section is devoted to design of reference solar cells, ways of their calibration. «Spectral characteristics of solar cells». In the given section techniques and the equipment for spectral characteristics measurement of thin-film solar cells, including multijunction cells are presented. «Current- voltage characteristics of solar cells». The section acquaints with techniques and the equipment for measurement of the current-voltage characteristics of solar cells and solar modules, as well as specific features of tandem thin-film solar cells modules current-voltage characteristics. «The photoinduced degradation of solar cells». The section acquaints with problems of the photoinduced degradation of thin-film solar cells and its characterization methods.
Technology of Solar Cells and Modules	**4 ECTS**	The course covers the following questions: Prospects of solar energy. Classification of the photoelectric converters of solar energy. Basics of silicon thin-film solar modules production. Main steps of silicon micromorph solar modules production. Quality of gases and materials used for silicon micromorph solar modules production. Basic procedures of fabrication of micromorph silicon solar modules. Substrate choice and preparation procedure. Deposition process of transparent conductive ZnO layer. Laser scribing. Deposition of photoactive absorbing amorphous and microcrystalline hydrogenated silicon layers. Back-end process: contacts application, edge isolation, lamination process, junction box assembly. Main trends of research for thin-film silicon photoelectric solar energy converters. Production lines for silicon based thin film solar modules. High-tech equipment used in silicon based thin film solar modules production.

Equipment and Automation of Solar Power Stations	**4 ECTS**	The course is devoted to studying of the equipment of solar power stations. Photovoltaic modules only represent the basic element of a solar power system. They work only in conjunction with complementary components, such as batteries, inverters, and transformers. Power distribution panels and metering complete the energy conversion process. In the course the characteristics of the equipment of solar power stations are discussed in details.
Laser Technologies and Processing in Manufacturing of Solar Modules	**4 ECTS**	The course contains information on physical fundamentals of laser technologies and architecture of industrial lasers. The requirements for lasers for microprocessing of materials are analyzed. Their main output parameters and features of operation are given. Case studies on applications of lasers for industrial processing of materials (mainly in microelectronics) are described. Separated part is dedicated to use of lasers in manufacturing the thin-film solar panels.
Microprocessor Techniques	**4 ECTS**	The course is dedicated to learning of the modern microprocessor families, microcontroller devices construction principles, microprocessor devices programming. During studying students get knowledge about components of the microprocessor systems; learn how to use cross-compilers for the software development in C programming language. Laboratory bench including modern high-efficiency ARM microcontroller and various input/output peripherals is used in the course lessons and laboratory practice.
Computer Technology and Simulation in Electronics	**4 ECTS**	The course is devoted to the study and practical application of computer technologies in the field of electronics. Elements of numerical simulation of micro- and nanoelectronic devices. This section discusses the features of solutions of systems of differential equations describing the operation of micro- and nanoelectronic devices. We consider the drift-diffusion and hydrodynamic model. The features of the numerical solution of one-dimensional problems on the basis of MathCAD (MathLAB). Features two-dimensional solutions of problems are considered on the basis of a package FlexPDE and Synopsys. Basics of programming, acquisition and processing of experimental data. Organization software in the form of problem-oriented software packages. The concept of virtual instruments. LabVIEW - a graphical programming system. Programming systems for collecting information. Programming of information processing systems (elements of digital signal filtering, etc.). Organization of distributed software and hardware systems.
Problems of Modern Electronics	**4 ECTS**	The course is dedicated to introduction of the latest trends and achievements in various promising fields of electronics. Studying of the course is reinforced by practical exercises aimed at acquiring the appropriate skills for formulating and solving problems when creating new components and technologies for nanoelectronics. As a result, students should be able to formulate goals of scientific research and technological development. This course provides a framework for a qualified activity of the graduates in the development of the field of nanotechnology and hardware components of nanoelectronics.
Foundations of Scientific Research	**2 ECTS**	The course is included into a base unit of a general scientific cycle of training of masters. The purpose of studying of discipline is acquaintance of masters with structure of scientific knowledge, with methods of scientific research, with functions of scientific theories and laws; expansion of their world outlook outlook; elaboration of ideas of criteria of scientific character and about requirements to which scientific research and its results has to answer.

Commercialization of Results of Scientific Research and Development	**2 ECTS**	Commercialization of the research work results is the process of involving them in the economic (commercial) turnover in order to ensure the innovative development of the national and international economy. The relevance of this discipline is due to the need to modernize the economy in the context of changing the existing technological structure based on the realization of the potential of high-tech branches of science and technology, including the "Digital Economy" program. The development and implementation of the research work results in the economic activities of organizations and enterprises is one of the key success factors for economic transformations. The implementation of the tasks of innovative development requires a qualified and competent assessment of the economic efficiency of projects focused on the production of high-tech products and the promotion of new technologies. The main goal of this discipline is to form a complex of knowledge, skills and practical skills of developing a business plan for the commercialization of innovative ideas in the form of creating new or improved types of products, goods, works and services studied in the course of R & D undergraduates. Mastering a phased methodology for business planning and design of various innovative projects will ensure the acquisition of competencies required in solving the problems of outputting the results to sales markets and assessing their economic efficiency.
Foreign Economic Activity of Organizations	**2 ECTS**	The expansion of foreign economic relations is a necessary prerequisite for the effective organization and reproduction of any macroeconomic system. This problem is particularly relevant in the current conditions of globalization and geopolitical instability. The purpose of the course is to provide future theoretical and practical knowledge in the field of organization, management and legal norms of international business in the context of Russian and world practice. The main task of the course is to arm master students with practical skills and modern methods of working in foreign markets. The course includes consideration of a wide range of issues related to the legal, organizational and practical plane of conducting foreign economic activity by Russian and foreign companies. The method of studying the course is based on a combination of lectures, seminars and practical exercises.
Solar Cells Based on Organic Materials	**2 ECTS**	The main types of solar cells based on organic materials are discussed, and an overview of their most important parameters and characteristics is provided. Requirements for organic materials that can be used in the basis of solar cells are considered. The main types and structures of organic solar cells are considered, including those containing fullerenes, colloidal quantum dots and arrays of other nanoparticles.
Multijunction Solar Cells Based on AIII–BV Compounds	**2 ECTS**	The following subjects will be considered during the study of this discipline: Band-gap structure of the materials for solar photovoltaics.Formation of the I-V curves of the one-junction and multijunction solar cells, their modification under illumination, connection with basic properties of the semiconductor materialPractical approaches to minimization of the optical, recombination and ohmic losses in solar cells. Principles of design and practical use of the concentrator solar cells. Reliability and life time of the solar cells and photovoltaic systems. Perspectives of the solar photovoltaics.

5. Efficient Electric Power Industry

Important characteristic of industry and technology at the moment is an energy consumption, which increases rapidly. Currently electric energy is a kind of goods, like a water or fuel. And consumer needs to control quantity and quality of energy provided to him. Industrial enterprises need to reduce power consumption for increasing their profit and for saving environment. In another hand they need to control quality of power they buy, and try to not decrease power quality in common network with their equipment.

Master's degree program **«Efficient Electric Power Industry»** is focused on ways to make technology more energy-efficient. Students get knowledge about modern electrotechnological equipment allowing to make more product spending less energy. They get practice in modeling processes in power network for optimization of processes modes. They learn also basic principles of energy audit which is main tool to control own power consumption.

Discipline	Credits	Description
Foreign Language	**6 ECTS**	This course is pointed on providing training courses for foreign citizens who had not studied the Russian language before. It includes language and speech models based on the requirements for the Elementary certification level. Achieving this level in Russian will satisfy the foreign students' basic communicative demands in social and cultural as well as in educational spheres of communication. The content of the program involves implementation of flexible training models, depending on the communicative purposes, native language and students' individual features.
Energy Management	**2 ECTS**	The subject deals with the principles of power systems management and marketing, especially in electric power systems. The classification of electric power systems costs is discussed and the electricity price is defined. Next, the function and problematic of the transmission power network in market conditions and on consumption side management is discussed.
Social Communication in Professional Environment	**2 ECTS**	The discipline is aimed at forming and developing general cultural competences of students including interpersonal professional communication skills, group/team management, adaptation to the changing environment conditions, ability to behave adequately in non-standard situations.
History of Science and Technology in the Field of Technical Systems	**2 ECTS**	The course is devoted to the study of a new physical phenomena discovery, new scientific theories and laws forming, basic ideas and technical solutions appearance in the field of electrical engineering, electro mechanics and control, which formed the automatic control science. Main stages in the history of the control theory and technology are overviewed. The discipline includes also the acquaintance with the history of St. Petersburg Electrotechnical University "LETI" and its main scientific schools.

Energy Saving and Quality of Electric Energy in Power Systems	**4 ECTS**	Subject introduces students to the issues of energy saving in technological processes and at power transportation. Particular attention is paid to energy audit as a survey, allowing to determine potential of energy saving and to evaluate influence of industrial equipment on power quality. Students get a practice in using modern tools for energy audits, performing instrumental survey as well as learn to make a power consumption balance.
Information Support in the Electric Power Industry	**5 ECTS**	The course is focused on ways to raise efficiency of information sup-port in power engineering, as well as on software packages intended for re-solving interconnected topics of performance analysis and decisions dis-patching. The issues of harmonizing all kinds of calculations not only ac-cording to their intended purposes but using a unified information and rule database are also addressed. The course goes into the topic of achieving higher accuracy of power system telemetry.
Power Converters	**4 ECTS**	The course is dedicated to converters of solar and wind energy. For ex-ample, students learn about four basic devices converting solar radiation in-to electric energy such as photovoltaic converters (semiconductor devices that convert solar energy into electricity directly), solar power sta-tions (solar modules that use highly concentrated solar radiation to power various equipment), and solar collectors (low-temperature solar heaters).
Alternative Energy	**5 ECTS**	This course addresses the important global issue of using an alternative energy. Alternative and renewable energies are changing the energy industry fast, creating a more diverse sector with huge opportunities for new technologies, new businesses and new ideas. The course provides in-depth knowledge of all major renewable technologies. Alternative energy technologies analysed include: bioenergy, geothermal, solar, wind power, hydropower and ocean power.
Efficient Industrial Installations	**6 ECTS**	The discipline introduces students to the issues of the use of electric heating in the industry; with efficient technologies and devices for heating, heat treatment and metal melting; with structural materials used in design and features of heating and melting units for ferrous and non-ferrous metals. Special attention in discipline is paid to the electrophysical and chemical processes proceeding of the metals in electric processing units and systems in general, to design features and scheme solutions of installations and devices. Theoretical bases of the arc discharge, a heat transfer and heat conductivity on examples of the real technological processes and devices used in the industry are studied.
Mathematical Modeling and Synthesis of Nonlinear Elements in Robotic System	**5 ECTS**	The course deals with the construction of various forms of nonlinear dynamic systems` mathematical models such as Volterra functional series, neural networks, wavelet neural networks, spline neural networks, polynomial perceptron networks, fuzzy inference adaptive networks and other. Practical issues of synthesis of polynomial and neutral filters and postcompensators of signal nonlinear distortion are considered.
Mathematical Modeling of	**5 ECTS**	The discipline «Mathematical Modeling of Objects and Automatic Control Systems» includes physical and mathematical bases of construction of models of objects and control systems, methodology of their research, the principles of creation

Objects and Automatic Control Systems		and research models in interactive engineering software environments.
Systems of Ensuring the Safety for Technical Control Devises	**3 ECTS**	The discipline considers general engineering issues in complex security. Also, principles of design and construction such systems are discussed. The focus is on the safety requirements in the test instrument. The discipline covers problems related to the features of technical equipment in terms of electromagnetic compatibility, ergonomic engineering and other.
Renewable Energy Automation Stations	**6 ECTS**	The course analyzes development trends of power system automation in conjunction to renewable-energy sources. Students learn about renewable-energy power plant automation namely battery charge controllers, batteries, DC-DC and DC-AC power inverters. Performance improvement methods for DC-DC and DC-AC power inverters also are addressed.
Intelligent Control Systems for Renewable Energy Stations	**5 ECTS**	The course is dedicated to the assembling of solar power plants, strategies leading to their better energy output, mathematical models, as well as methods for the design of such objects. The students also learn about the system that controls rotation drives of solar panels for ensuring maximum battery voltage during charging. Various issues of intelligent electronic de-vices (IED) such as basic information modules of protective relays and bay controllers are addressed as well.
Modeling of Processes in Power Industry	**5 ECTS**	The discipline introduces students to methods of solving problems of electrotechnologies at electroenergetic on the base of mathematical modelling methods and numerical tests. All stages of the problem solution (electromagnetic and thermal), starting from choice of solution method and ending with creation of program in algorithmic language, are shown. Finite differential and finite element methods are considers for solving differential equations. Also provides analytical and combined solution methods. Presents solution of inverse electromagnetic problems. On the base of commercial program ANSYS provides solution problems of electromagnetic field and thermal conductivity for two- and three-dimensional cases.

6. Systems and Technologies in Digital Healthcare (in the field of Biomedical Engineering)

The educational program provides training for specialists in biomedical engineering to use modern information, telecommunication and computer technologies, and telemedicine for remote monitoring and health assistance of outpatients with chronic diseases. Using the aforementioned technologies, specialists will be able to reveal the exacerbation of chronic diseases in real time and to monitor the health of patients during treatment. The formation of professional skills and competencies required for professional activities in the field of digital medicine will be carried out by developing and incorporating new disciplines into the program. These disciplines are aimed at automating the design of remote monitoring systems using artificial intelligence for processing and analysis of biomedical signals, information, and medical assistance of patients during monitoring.

Discipline	Credits	Description
Telemedicine Systems and Technologies	**4 ECTS**	The discipline includes the theoretical and practical aspects of the telemedicine systems development and maintenance. Technologies for information transmitting to near and far distances, data transfer protocols, used data formats, encryption methods, the basics of database design, as well as technologies for building and configuring local networks are included in the discipline content. In addition to technical issues, issues of legal regulation of the telemedicine region in Russia are highlighted.
Monitoring Systems in Digital Healthcare	**5 ECTS**	Students get basic knowledge in the field of registration of biomedical signals used to assess the current state of human health in telemedicine monitoring systems, such as electrocardiogram, pulse wave, blood pressure, respiration rate, etc. practical exercises, students will learn a basic set of sensors for registering biomedical signals, current trends and approaches to instrumental support of remote monitoring systems. During laboratory work, students will gain the skills to register biomedical signals and process them using the modern system Biopac Student Lab.
Motion Analysis Systems and Technologies	**4 ECTS**	This is an introductory course in movement and gait analysis. The main aim of this course is to introduce students to the techniques and methods of gait analysis and give them knowledge and tools to solve biomechanical problems, robotics, to improve rehabilitation techniques, research and treatments programs for people with different disabilities of the musculoskeletal system.
Methods of Computer Processing & Analysis of Medical and Biological Data	**4 ECTS**	The discipline is devoted to the study of different methods of computer processing of biomedical and environmental data. It discusses methods for presenting data, data compression techniques, statistical methods of experimental data processing. Much attention is paid to the classification of multidimensional observations.

Bases of Management & Marketing at Medical Industry	**3 ECTS**	The course covers issues related to planning and managing the marketing activities of an enterprise, in particular: the marketing concept, methods for assessing the competitiveness of high-tech products, components of the demand generation and sales promotion system and the main types and categories of services in medical and technical enterprises profile. The system of development and introduction of medical devices, the procedure for registration of medical devices in the Russian Federation and the Eurasian Union, as well as the main directions of foreign economic activity (FEA) enterprises are considered.
Automated Analysis of Images	**4 ECTS**	The problems of image analysis and processing are studied. Focus is made on specifics of digital raster images of medicalbiological objects – medical images. The procedure of obtaining medical images is briefly described, with attention to the specific nature of visual perception of images on monitors. Basic methods of images analysis and processing are discussed, along with the examples of application to medical images and the issues of images compression and quality estimation addressed. The studied theory is supported by practical training of automated image processing techniques.
Automation of Biomedical Research	**4 ECTS**	The discipline provides training in the field of biotechnical systems and human control systems. It contains innovative technologies that are used to automate biomedical research, as well as the basic principles of building systems that implement these technologies. The course discusses the problems arising in the synthesis of systems, their methodological, information, and instrumental support.
Simulation on Bioengineering Systems	**3 ECTS**	The discipline is dedicated to modeling in biomedical engineering and is aimed on widening the knowledge and experience in applying mathematical apparatus for different applications in medical and technical sciences. Learning material covers a broad range of data-driven and theoretical models, including models based on differential equations, finite-state machines, Markov chains, queueing systems, Petri nets and time series among others. The course is supplemented with laboratory works dedicated to aspects of data-driven modeling in MATLAB, Simulink and R.
Maintenance and Repair of Modern Medical Equipment	**3 ECTS**	The course deals with the installation, commissioning, control of the technical condition, periodic and routine maintenance, repair of medical equipment. After studying the basic principles and legislative issues, the specifics of the implementation of the declared processes are considered in relation to certain types of medical equipment: X-ray, computed tomography scanners, ultrasound scanners, anesthetic, and laboratory equipment. During practical classes students develop a plan for technical maintenance and perform tasks of finding and eliminating of typical malfunctions.
The Information Systems in	**3 ECTS**	This Masters' level course introduces the fundamentals of information systems used for: managerial and clinical support in healthcare; comparison to healthcare systems in other countries; electronic health records and the use of medical

Rehabilitation		databases; further exploration of medical databases and manipulation for decision support including evidence-based practice. Students will learn how to use medical databases, store and use statistical tools such as IBM SPSS statistics and IMB SPSS Modeler for evidence-based clinical research. The course has been designed to give both theoretical and practical knowledge
Modern Problems of Biomedical Engineering	**3 ECTS**	The discipline is intended for students studying in medical-technical areas of education. This course introduces students with the current problems and the most promising areas of biomedical engineering (BMI). In particular, the issues of application of nanotechnology in medicine, modern Xray techniques, and systems for contactless recording of human physiological indicators are considered. The study of the discipline will allow future masters to more freely navigate the main problems of basic and applied research in the field of biomedical engineering, to identify its promising areas and practical applications.
Advanced Methods and Tools for Biomedical Data Analysis	**3 ECTS**	The course program includes basic machine learning algorithms with an emphasis on their mathematical description and specific properties of biomedical datasets. The issues of data preparation, selection of significant features, variance analysis, decision trees and forests, neural networks and Big Data technologies are discussed. In practical and laboratory classes, students learn to apply theoretical knowledge to practical problems of biomedical data analysis using Python programming language.
Bioengineering Systems & Technologies	**4 ECTS**	The discipline forms the basic knowledge of bioengineering systems synthesis and technologies application. Principles of the bioengineering systems development, generalized structure of the bioengineering system, system's control contours, channels of informational interaction between technical units and biological objects, the stages of information transformation during system functioning are considered.
Interdisciplinary Project	**3 ECTS**	Interdisciplinary project represents a student's independent research development and assumes advanced study by students of particular problems of professional activity connected with the creation and maintenance of medical rehabilitation systems.
Social Communication in a Professional Environment	**2 ECTS**	The aim of the course is to discuss some important problems of theory and practice interpersonal communication in professional environment. The following issues are discussed in the course: situate and psychological factors of interpersonal communication, verbal and nonverbal practices of communication, active listening, specific ways of interpersonal pressure, influence and manipulation, emotional management, types of corporate culture and teambuilding.

Commercialization of Research and Development Results	**2 ECTS**	The subject of the study is the methodology for predicting of potential outcomes of scientific research results implementation. Theoretical foundations of innovative business planning, the study of the structure and content of a business plan, planning of innovative product lifecycle, prediction of costs and revenues for the implementation of business ideas and evaluation of the innovation project are considered.
Russian Language	**2 ECTS**	The course is aimed at providing training for foreign citizens who had not studied the Russian language before. It includes language and speech modules based on the requirements for the Elementary certification level. Achieving this level in Russian will satisfy the foreign students basic communicative demands in social, educational and cultural spheres.

7. Automation and Mechatronics

Students learn the principles of robotics and mechatronics, mechatronic and robotic actuators, modern technologies of microcontroller application. The program gives students a deep theoretical knowledge of modern methods of automatic control theory, in particular, the methods of analysis and design of nonlinear, adaptive and intelligent control systems.

The program provides students with a broad knowledge and skills in the field of automation of production processes and equipment, as well as in the field of mechatronic devices and control systems. Study of network technologies, issues of SCADA-systems construction, practical use of real-time systems are important parts of the program.

Discipline	Credits	Description
Nonlinear, Adaptive and Intelligent Control Systems	**6 ECTS**	Studying the basics of the theory of nonlinear, adaptive and intelligent (fuzzy and neural network) control systems. The material of the course set out: the method of Lyapunov functions, including elements of its design; square and circle criteria for absolute stability; the study of periodic solutions, Poincare type methods and Galerkin harmonic balance; research methods of nonlinear dynamics, linear stability analysis, stability of periodic, quasi-periodic and chaotic solutions, local and nonlocal bifurcation; searchless algorithms and adaptive control systems, basic structure, synthesis methods, speedgradient method; variable structure system. Fuzzy and neural systems - intelligent control systems.
Modern Methods of Control Theory	**5 ECTS**	In the first part of the course material set out issues of stochastic nonlinear dynamics for deterministic systems of low order. Used the techniques of linearization for non-periodic and periodic attractors. Considered the local bifurcations of a saddle equilibrium state, a limit cycle and structures of two-dimensional torus, and nonlocal bifurcations of these attractors. In the second part of the paper describes the construction of robust regulators for objects with limited uncertainty (H∞–theory) from the perspective of the external approach. Presents the main mathematical results of robust stability, the problem of robust control and robust structures of the regulators.
Mathematical Modeling and Synthesis of Nonlinear Elements	**5 ECTS**	The course deals with the construction of various forms of nonlinear dynamic systems` mathematical models such as Volterra functional series, neural networks, wavelet neural networks, spline neural networks, polynomial perceptron networks, fuzzy inference adaptive networks and other. Practical issues of synthesis of polynomial and neutral filters and postcompensators of signal nonlinear distortion are considered.
Mathematical Modeling of Objects and Automatic Control Systems	**5 ECTS**	The discipline includes physical and mathematical bases of construction of models of objects and control systems, methodology of their research, the principles of creation and research models in interactive engineering software environments.

Electric and Hydraulic Drives of Mechatronic and Robotic Systems	**7 ECTS**	In this course students study the principles of operation of electric and hydraulic drives of various types used in modern mechatronic and robotic devices and control methods of actuators and methods for their calculation and modeling. As well as the examples of different types of actuators are presented in this material.
Electromechatronic Complexes and Systems	**6 ECTS**	In this course students will study the process of electromagnetic and electromechanical energy conversion processes associated with functional and design combining in EMTC electromechanical converter with electronic components. We consider the structure and operation of EMTC of an example with synchronous machines and information type EMT systems. The technique of calculating the parameters and characteristics of EMTC are considered. Practical and laboratory classes are conducted with the development of methods for the preparation and analysis of EMTC performance.
Systems of Ensuring the Safety for Technical Control Devises	**3 ECTS**	The discipline considers general engineering issues in complex security. Also, principles of design and construction such systems are discussed. The focus is on the safety requirements in the test instrument. The discipline covers problems related to the features of technical equipment in terms of electromagnetic compatibility, ergonomic engineering and other.
Microcontroller-Based Control Systems	**6 ECTS**	This course will give to the future specialists skills of algorithmization and further implementation of their automation ideas using microcontrollers. The educational process covers the lecture hours and practical hours while the students have the opportunity and facilities for the microcontroller programming and automatic control systems design.
Mechatronic Systems and Robotics	**5 ECTS**	The discipline covers principles of mechatronic and robot-based technological complexes design. Robotic systems drives, questions of mathematical description and simulation of robots and mechatronic machines are discussed. The discipline is supported by a large number of practical and laboratory classes and students' self studies on the basic sections of the programme. Testing and current control of students' knowledge are provided in order to ensure the quality control of mastering the discipline by students.
Adaptive Control in Mechatronics and Robotics	**5 ECTS**	The greatest attention in this course is paid to the questions of the following areas: mechanics systems, mechatronics, dynamic systems, automatic systems with adaptive control, automatic systems with modal control, theory of stability, and theory of state recovery.

Computer-based Technologies of Control in Technical System	**5 ECTS**	The discipline is intended to provide full representation about modern information technologies and software used in the control systems, implemented on the basis of information and digital systems, primarily - in industrial processes. Presentation of the material is based on universal regulations applicable to the control of any complex system. The functional, organizational, informational, software and hardware aspects of computer-aided control processes are given in detail. Practical development of computer technologies is carried out in a laboratory-based, consisting of research laboratory stands, equipped with the modern generation of industrial controllers.

8. Heritage Science

"Heritage Science" is interdisciplinary Master of Science program, which aims to give students the technical background allowing them to resolve the most actual tasks of Cultural Heritage preservation by means of combined use of engineering and humanitarian knowledge.

This MSc program provides students with engineering knowledge about the current achievements in the use of physical, chemical, laser and optoelectronic techniques in Cultural Heritage preservation. The process of education includes lectures, practical classes and training laboratory workshops that will acquire and/or upgrade understanding of students of complex problems of restoration, examination, attribution, storage and exhibiting of artworks and their solution by means of use of achievements of modern science.

Discipline	Credits	Description
Fundamental Courses		
Materials of Cultural Heritage Objects	**4 ECTS**	The objectives of this course is to provide information on the properties of the most common minerals and rocks as well some metals and alloys, which are used in architecture and arts and crafts. Basic knowledge on fundamentals of mineralogy (including chemical bonds and crystal structures, crystal growth, the physical properties of minerals and mineral identification techniques) and petrography (the different groups of rock-forming minerals, and classification of rocks based on their mineral contents and textures) are discussed. Besides, the basic laws of mineral formation in natural and technological processes are given.
Environmental Impact on Materials, Ageing and Deterioration of CH Objects	**4 ECTS**	This course gives students basic information about the environmental risk to cultural property caused by physical, chemical and biological factors. Also students will study impact of environmental factors of natural and anthropogenic nature. The course provides general information about environmental monitoring as one of the most effective modern instrument in the field of Cultural Heritage preservation around the world. In addition, the course includes practical laboratory works that allows one to master the methods of assessing the microclimate in the premises for the sustainable protection of CH objects.
Chemistry in Restoration	**4 ECTS**	This discipline involves the study of the chemical properties of both restored and restoration materials used in the conservation and restoration of various objects of cultural heritage. The diversity of the nature of these materials determines the problems that restorers encounter in the process of their activities. The objectives of this discipline are the development of the theoretical base, which includes questions of general, inorganic, organic, physic-chemical, colloidal and analytical chemistry, as well as the acquisition of practical skills in working with chemical compounds necessary for both research and restoration work itself.
Biology in Restoration	**3 ECTS**	The objectives of this course is to provide information on the theoretical aspects of the of materials biodeterioration problem, methods for evaluating and studying bio-damage of monument materials, mechanisms

		of destruction processes in the anthropogenic environment and protection of materials from degradation in restoration practice. The role of microorganisms (microscopic fungi, bacteria and algae) in the destruction of monuments in different environment (in the open air in different climates, in the conditions of Museum storage) is discussed. The course will cover examples of biological deterioration to Cultural Heritage objects created from various materials: natural and artificial stone, wood, paper, etc. Special attention is paid to the interaction of biological and physical-chemical factors in the destruction of materials.
Opto-electronic Techniques for CH Materials Characterization	**3 ECTS**	The course covers the most widely used methods, techniques and equipment for materials characterization such as light photometry, UV/Vis spectrometry, fluorescence spectroscopy, Fourier transform infrared spectrometry (FTIR), Raman spectroscopy, ellipsometry, scanning electron microscopy (SEM), atomic force microscopy (AFM), X-ray diffraction analysis (XRD) and some others. The course is focused on the basic physical principles, advantages and limitations of each method and their practical application for the investigation and characterization of Cultural Heritage objects.
Physical Non-destructive Methods of Examining of CH Objects	**4 ECTS**	This course gives a basic knowledge about physical principles and applications of main kinds of non-destructive methods of examining of Cultural Heritage objects based on the use of X-rays, acoustic and electromagnetic waves. Among non-destructive techniques Infrared Termography, Nuclear Magnetic Resonance, X-ray Digital Radiography and 3D Computed Tomography will be considered. Also basic knowledge of Ion Beam Analytical techniques, including PIXE (Particle Induced X-ray Emission), PIGE (Particle Induced Gamma-ray Emission) and RBS (Rutherford Backscattering Spectrometry) will be discussed.
Laser Techniques in Restoration and Analysis of Artworks	**4 ECTS**	This course gives to students a basic information about the use of laser techniques in Cultural Heritage preservation. Special attention is paid to consideration of laser cleaning of artworks. Basic physical principles of laser cleaning technology are considered and most important case studies connected with cleaning of CH objects created from different materials are overviewed. Use of 3D laser scanning for documentation, reconstruction and replication of CH objects is considered too. Furthermore, information about physical basics and practical use of other laser measuring techniques (LIBS, LIF, Laser Doppler Vibrometry and others) intended for analysis and non-destructive testing of artworks is presented.
Computer Methods Applications in CH Preservation	**4 ECTS**	The purpose of this course is to study the impact of computer technology on art, as well as the specifics of the interaction between art and science and the results of this interaction. The course considers the use of information technologies for study and restoration of artworks, including computer reconstruction of lost parts of Cultural Heritage objects, as well as their archiving, museification and digitization (3D laser scanning, digital photography in the infrared range, etc.) and creation of copies. In addition, the use of computer methods for educational work (virtual museum) and scientific research of artworks (including their authentication and dating) is considered. The

		issues connected with introducing the blockchain technology to the art market using the case studies of use of new services, platforms and crypto auctions are also discussed.
Basic Special Disciplines		
Brief History of Art	**4 ECTS**	Brief history of art course serves to navigate in diverse historic styles in art, as ability to distinguish general styles is an obligatory skill in expertise and attribution of art pieces. The course is aimed at formation of skills of study of objects of art in their historical development and historical contexts. Another skill to be formed is the ability to compare different periods in art history and different groups of artworks belonging to different geographical and chronological locations. As for typological groups of artworks, general division is one to works of fine and decorative art.
Introduction in Heritage Objects Conservation	**4 ECTS**	The course is focused at basic ideas of conservation/restoration science and practice. A short excursus to the history of conservation theory and practice is aimed onto deeper understanding of its current ideas and methods. Definitions between operative and preventive conservation are discussed. Methodology and methods of practical conservation/restoration are analyzed, traditional and innovative ones being compared. The question of professional ethics in artworks restoration is one more essential topic of the course.
Expertise and Attribution of Artworks	**4 ECTS**	Since correct examination and attribution of artworks in most cases is possible only with a combination of various analytical methods, the course focuses on the consideration of art criticism methods of examination and attribution of works of art. None artwork cannot be attributed if it is not analyzed in terms of its state of preservation, technique of creation, composition, origin, previous restorations, and so on. Therefore, the course includes the study of various methods of analysis of fine and decorative arts. In particular, since stylistic analysis is a mandatory part of this process, the course includes consideration of the basic concepts of composition in the visual arts. Important features of existence, origin and restoration that serve as indirect proof of the authenticity of an art object and should be analyzed in the process of attribution are also studied in this course.

9. Technology Innovation Management

The program is intended for graduates of engineering and management departments who would like to work on their innovation, technology and engineering skills. Master's students learn the basics of project management, marketing and innovative activity. Students also learn how to manage innovations in a business and implement new technologies in resource management of a knowledge-intensive manufacturing company.

The program provides students with international-level education which is crucial in the era of digital economy. After graduation students can be hired by leading world technology companies.

Course	Credits	Course	Credits
Basics of Cyber-Physical Systems Management	5 ECTS	Finance and Economic Fundamentals of Business Process Modelling	4 ECTS
Methods of Scientific Research	5 ECTS	Knowledge Management at hi-tech Enterprises	3 ECTS
Technology Transfer	4 ECTS	Network Technologies	3 ECTS
Management of Technological Innovations	4 ECTS	Intellectual Property Management	3 ECTS
Advanced Strategic Analysis	5 ECTS	International Business Environment	3 ECTS
Project Management	3 ECTS	Innovation Project Evaluation	2 ECTS
Technological Audit	2 ECTS	Multi-Agent Systems	ECTS
Open Innovation	3 ECTS	Information Technologies for Logistics	3 ECTS
Theory and Practice of Organizational Changes	3 ECTS	Econometric Analysis of Innovation Changes	2 ECTS
Organization of Digital Communications	2 ECTS	Business English	3 ECTS