DANYLO HALYTSKY LVIV NATIONAL MEDICAL UNIVERSITY

Biophysics department

APPROVED
First Vice Rector on
Scientific and Pedagogical Work
Assoc. Prof. Iryna SOLONYNKO
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DISCIPLINE PROGRAM

MEDICAL AND BIOLOGICAL PHYSICS

OK 6

Second (master's degree) level of higher education
Field of Knowledge 22 "Healthcare"
specialty 221 "Dentistry"

Discussed and approved
at the educational-methodical meeting
of the Biophysics department
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Approved
by the Profile Methodical Board
of the Faculty of Foreign Students
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INTRODUCTION

The academic program of the discipline "Medical and biological physics"
according to the Higher Education Academic Standard of the second (Master's) level education sector 22 "Healthcare"
speciality 221 "Dentistry"
Education Program Master of Dentistry

The description of the discipline "Medical and biological physics" (Annotation).

Academic program of the discipline "Medical and biological physics" provides knowledge about physical processes and physicochemical phenomena in biological environments, the influence of external factors on the human body, the physical basis of diagnostic and physiotherapeutic methods used in modern dentistry.

According to the curriculum, the discipline "Medical and Biological Physics" is studied by the I year students. The program of the discipline is structured into 2 chapters as follows:

The chapter 1. Biophysics of biological systems.

In the chapter 1 thermodynamics of biological processes, biophysics of cellular processes and complex systems, in particular biological membranes, circulatory system, sensory systems, molecular mechanism of cellular processes are considered.

The chapter 2. Physical bases of methods of medical imaging and therapy.

In the chapter 2 the effects of environmental factors on the human body: mechanical waves, electromagnetic waves of different ranges and parameters, non-ionizing and ionizing radiation; methods of diagnosis and therapy, methods of qualitative and quantitative research of drugs; medical electronic equipment for medical imaging, registration and therapy are considered.

Structure of the discipline	**Quantity of credits, hours, from them**				**Year of study, semester**	**Form of the control**
	Total	**Auditory**		**ISW**		
		Lectures	Practical classes			
Name of the discipline: "Medical and Biological Physics" Chapters 2	**4 credits / 120 hours**	**8**	**52**	**60**	**I course (I, II semesters)**	**Differential credit**
Chapter 1	**1,8 credits / 55 hours**	**6**	**20**	**28**	**I course (I and II semesters)**	
Chapter 2	**2,2 credits / 65 hours**	**2**	**32**	**32**	**I course (II semester)**	**Differential credit**

The subject of study of the discipline "Medical and Biological Physics" is the physical processes occurring in biological environments and the influence of external

factors on living organisms, and and the physical basis of diagnostic and physiotherapeutic methods used in dentistry.

Interdisciplinary links:

integrates with the following disciplines:

Medical biology, parasitology, genetics;

Medical chemistry;

lays the foundations for students to study such disciplines:

Biological chemistry;

Bioorganic chemistry;

Physiology, including physiology of the masticatory apparatus;

Pathophysiology;

Histology, cytology and embryology;

Propaedeutics of internal medicine;

Hygiene and ecology;

Radiology;

Ophthalmology,

Otorhinolaryngology;

Propaedeutics of therapeutic dentistry;

Therapeutic dentistry.

1. Aim and objectives of the academic discipline

1.1. The purpose of teaching the discipline “Medical and Biological Physics” is to deepen and improve knowledge, skills and practical understanding of biophysical processes in alive organisms; physical methods of disease diagnosis and research of biological systems; the impact of physical factors on the human body in its treatment; physical properties of materials used in dentistry; physical properties and characteristics of the environment.

1.2. The main tasks of studying the discipline “Medical and Biological Physics” are study:

- general physical and biophysical laws that underlie human life;
- physical bases and biophysical mechanisms of action of external factors (fields) on the systems of the human body;
- physical phenomena that underlie diagnostic and physiotherapeutic (therapeutic) methods used in medical practice.

1.3 **Competence and learning outcomes**, the formation of which is facilitated by discipline (the relationship with the normative content of higher education graduates’ training, formulated in terms of learning outcomes of Higher Education Standard).

In accordance with the requirements of Higher Education Standard, discipline ensures students' acquisition of **competences:**

– *integral*:

The ability to solve complex tasks and problems in the field of health care in the specialty "Stomatology" in professional activity or in the learning process, which involves conducting research and/or implementing innovations and is characterized by the uncertainty of conditions and requirements.

– *general:*

GC 1 The ability for abstract thinking, analysis and synthesis.
GC 2 Knowledge and understanding of the subject area and understanding of the professional activities.
GC 3 The ability to apply knowledge in practical situations.
GC 4 The ability to communicate in the official language both orally and in writing.
GC 5 Ability to communicate in English.
GC 6 Skills of information and communication technologies application.
GC 7 The ability to search, work out and analyze information from various sources.
GC 9 Ability to identify, pose and solve problems.
GC 11 The ability to work as a team member
GC 12 The desire to protect the environment.

– *special (professional):*

PC 2 Ability to interpret the results of laboratory and instrumental research.
PC 4 Ability to plan and implement measures for the prevention of diseases of organs and tissues of the oral cavity and maxillofacial region.
PC 13 Ability to assess the impact of the environment on the health of the population (individual, family, population).

Details of the competencies are set out below in the competency matrix table.

COMPETENCY MATRIX

№	Competence	Knowledge	Skills	Communication	Autonomy and responsibility
1	2	3	4	5	6
	Integral competence				
	The ability to solve complex tasks and problems in the field of health care in the specialty "Stomatology" in professional activity or in the learning process, which involves conducting research and/or implementing innovations and is characterized by the uncertainty of conditions and requirements.				
General competence					
1	Ability to abstract thinking, analysis and synthesis	Know methods of analysis, synthesis and further modern learning.	Be able to analyze information, make informed decisions, be able to acquire modern knowledge.	Establish appropriate links to achieve goals.	Be responsible for the timely acquisition of modern knowledge.
2	Knowledge and	Know structure	Be able carry out	Ability to	Be responsible for

	understanding of the subject area and understanding of the profession.	of professional activity.	professional activities that require updating and integration of knowledge.	effectively form a communication strategy in professional activities.	professional development, the ability to further professional training with a high level of autonomy.
3	Ability to apply knowledge in practical situations.	Know specialized conceptual knowledge.	Be able to solve complex problems and problems that arise in professional activities.	Clear and unambiguous communication of one's own conclusions, knowledge and explanations that substantiate them to specialists and non-specialists.	Responsible for making decisions in difficult circumstances.
4	Ability to communicate in the state language both orally and in writing	Have a perfect knowledge of the state language	Be able to apply knowledge of the state language, both orally and in writing.	Use the state language in professional and business communication and in the preparation of documents the state language.	Be responsible for the preparation of documents in the state language.
5	Ability to communicate in English.	Have a basic knowledge of English.	Be able to apply knowledge of English.	Use English in professional activities.	Be responsible for the use of English in professional activities.
6	Skills in the use of information and communication technologies;	Know: information and communication technologies used in professional activities.	Be able to: apply information and communication technologies in the professional field, which requires updating and integration of knowledge.	Apply information and communication technologies in professional activities.	Be responsible for the development of professional knowledge and skills.
7	Ability to search, process and analyze information from various sources.	Know the methods of information retrieval, processing and analysis	Be able to search, process and analyze information	Use different methods of information processing.	Be responsible for information management.
8	Ability to identify, pose and solve problems.	Know the responsibilities and ways to accomplish the tasks.	Be able to set goals and objectives to be persistent and conscientious in the performance of duties.	Establish interpersonal relationships to effectively perform tasks and responsibilities.	Be responsible for the results of solving problems and scientific problems.
9	Ability to work in a team	Know the tactics and strategies of communication, laws and ways of	Be able to make informed decisions, choose ways and strategies	Use communication strategies and skills of	Be responsible for effective teamwork

		communicative behavior.	of communication to ensure effective teamwork.	interpersonal interaction.	
10	The desire to preserve the environment.	Be able to form requirements for themselves and others to preserve the environment.	Know the problems of environmental conservation and ways to preserve it.	Make proposals to the relevant authorities and institutions on measures to preserve and protect the environment.	Be responsible for preserving the environment.
Special (professional) competence					
1	Ability to interpret the results of laboratory and instrumental research.	To know the influence of physical factors on the human body, standard methods of laboratory and instrumental research.	Be able to analyze research results.	It is reasonable to choose and evaluate research results.	Be responsible for deciding on the evaluation of research results.
2	Ability to plan and implement measures for the prevention of diseases of organs and tissues of the oral cavity and maxillofacial region.	Know the biophysics of human organs, human systems and physical characteristics of dental materials.	Be able to analyze the biophysical indicators of the work of organs, human systems and determine the physical characteristics of dental materials.	It is reasonable to form and bring to the patient, specialists conclusions about the need for medical manipulations.	Responsibility, independence.
3	Assessment of the impact of the environment on the health of the population (individual, family, population).	Know: environmental factors that adversely affect public health.	Be able: assess the state of the environment and adverse health effects.	Set conclusions about the state of health of the population, based on data on the relationship with environmental factors.	Be responsible for correct conclusions about the negative impact of environmental factors.

Integrative program results outcomes for the formation of which contributes to the academic discipline.

PRO 14 Analyze and evaluate state, social and medical information using standard approaches and computer information technologies.

PRO 15 Assess the impact of the environment on the health of the population in a medical institution by standard methods.

PRO 17 Adhere to a healthy lifestyle, use the techniques of self-regulation and self-control.

PRO 20 Organize the necessary level of individual safety (own and persons cared for) in case of typical dangerous situations in the individual field of activity.

Learning outcomes for the discipline. As a result of studying "Medical and Biological Physics" the student has to

know:
- general physical and biophysical patterns that underlie human life;
- physical bases and biophysical mechanisms of action of external factors on the systems of the human body;
- physical bases of diagnostic and physiotherapeutic (therapeutic) methods used in medical equipment.

able to:
- analyze physical processes in the body, using physical laws and phenomena;
- explain the principle of operation of medical equipment;
- use medical equipment applied in dentistry for treatment and diagnosis, optical and quantum-mechanical devices, radiometric and dosimetric control devices;
- substantiate the indications and contraindications to the physiotherapy method;
- to analyze the effect of environmental factors on the body.

2. Informational content of the discipline

4 ECTS credits (120 hours) are allocated for discipline. The academic program of the discipline is structured into 2 chapters.

Chapter 1. Biophysics of biological systems

Topic 1. Thermodynamics of open biological systems.

Specific goals:
- interpret the basic principles of thermodynamics of open biological systems;
- apply the thermodynamic method of studying medical and biological systems;
- analyze intermolecular interactions in biopolymers;
- to interpret the processes of ordering in physical, chemical and medical-biological systems;
- explain the importance of thermodynamics.

Subject and methods of biophysics, connection with other sciences. The main sections of biophysics.

Thermodynamics of equilibrium states. Basic concepts of thermodynamics. The first law of thermodynamics. Enthalpy. Hess's law. Calorimetry. The second laws of thermodynamics. Thermodynamic potentials. Change of standard free energy. Chemical potential. Electrochemical potential. Thermodynamics of biological processes.

Thermodynamics of irreversible processes (linear law for flows and

thermodynamic forces, cross transfer processes, Onsager ratio, entropy production, flow conjugation, steady state, Prigogine's theorem).

Topic 2. Biophysics of membrane processes

Specific goals:

- analyze the structural elements of biological membranes, their physical and dynamic properties;
- explain the mechanisms of membrane transport;
- interpret Fick's equation, membrane permeability coefficient, diffusion rate, Nernst-Planck equation, electrochemical potential, Theorell equation;
- to analyze the molecular organization of active transport on the example of Na^+-K^+ pump operation.
- explain the ionic nature of the resting membrane potential (Nernst equilibrium potential, diffusion potential, Donnan potential, stationary Goldman-Hodgkin-Katz potential);
- to interpret the mechanism of action potential, speed and its propagation in axons.

Structural elements of biological membranes. Physical properties of biomembranes. Liquid crystalline state of biomembranes. Dynamic properties of membranes. Types of gradients. Passive transport of substances through membrane structures: diffusion, osmosis, filtration. Fick's equation. Membrane permeability coefficients for a given substance. Nernst-Planck equation. Electrochemical potential. Theorell equation. Active transport, main types. Molecular organization of active transport on the example of Na^+ -K^+ pump. Secondary active transport.

The resting membrane potential and the action potential. Nature of the resting membrane potential (Nernst equilibrium potential, diffusion potential, Donnan potential, stationary Goldman-Hodgkin-Katz potential).

Action potential. Ionic mechanisms of the action potential. Propagation of action potential. Cable theory. Equivalent electrical circuit of the excitable membrane. Phenomenological Hodgkin-Huxley equations. The concept of gate ion currents. Propagation of action potential in nerve fibers.

Topic 3. Fundamentals of biomechanics, bioreology and hemodynamics

Specific goals:

- interpret the basic physical concepts and laws of biomechanics, bioreology and hemodynamics;
- to interpret mechanical models of viscoelastic properties of biological tissues;
- determine the Young's modulus of biological tissues;
- explain the phenomena of surface tension and viscosity of liquids;
- to interpret gas embolism as a physical phenomenon;
- demonstrate skills in measuring the coefficients of surface tension and viscosity of liquids;
- explain the physical basis of methods for measuring blood viscosity and

methods for measuring blood pressure and circulatory rate.

Basic concepts of mechanics of translational and rotational motions. Equations of motion, conservation laws. Elements of biomechanics. Human musculoskeletal system. Dynamic and statistical work of the person at various kinds of its activity. Ergometry. Measurement methods and instruments to analyze the biomechanical characteristics.

Biophysics of muscle contraction. Muscle contraction. The Hill Equation. Power of single contraction. Smooth muscle biophysics. Biomechanics and energy of the heart muscle.

Fundamentals of bioreology. Deformation properties of biological tissues. The Hooke's law. Young's modulus and Poisson's ratio. Fluidity and stress relaxation.

Internal friction, viscosity. Newton's formula for the force of internal friction. Newtonian and non-Newtonian fluids. Methods and viscosity measurement devices. Rheological properties of blood. Blood viscosity and it applying to the disease's diagnosis. Laminar and turbulent fluid flow. Reynolds number.

Basic hemodynamic principles. Stationary fluid flow. The continuity equation. The Bernoulli equation. Linear and volume velocities. The basic equation of fluid dynamics. Flow of viscous liquids. Poiseuille and Gauguin-Poiseuille formulas. Hydraulic resistance. Biophysics of blood circulation. Work and power of the heart. Measurement of blood pressure and blood flow velocity. Pulse wave. The main indicators of hemodynamics.

Surface tension. Surface tension coefficient. Methods of its definition. Surfactants. Gas embolism.

Biophysics of respiration. Biomechanics of inhalation and exhalation. Pulmonary distension. Resistance to breathing. Breathing work.

Topic 4. Biophysics of sensory systems. Biophysics of hearing. Biophysics of the visual analyzer.

Specific goals:

- classify mechanical oscillations and waves;
- interpret the basic physical concepts and laws of bioacoustics;
- explain the physical bases of audiometry as a method of hearing research;
- demonstrate skills with an audiometer;
- explain the physical and biophysical characteristics of the human eye and the mechanisms of photoreception.

General characteristics and principles of operation of the sensor system. The structure of the analyzer. Research methods sensory systems. Properties of sensory receptors. Varieties of receptors and sensations. Classification of sensory receptors and sense organs. Basic biophysical properties of sensory systems and receptors.

Basic kinematic and dynamic characteristics of mechanical oscillations and waves. The mechanism of propagation of acoustic waves.

Objective and subjective characteristics of sound. Intensity, intensity level,

loudness, their units. Threshold of audibility and pain. Weber-Fechner law. Biophysical bases of auditory sensation. Coding of information in the auditory analyzer. Physical basics of audiometry. Audiogram and curves of equal loudness.

Laws of geometric optics. Basic photometric quantities. Optical power of the eye. Refractive eye surfaces. Refractometry. Eye refraction at norm and pathology. Accommodation. Aberration. Diffraction. Eye resolution. Day and dimm vision. Eye sensitivity. Defects of the eye and their correction. Molecular mechanism of visual reception. Photoisomerization of rhodopsin. Color vision. Spatial vision.

Chapter 2. Physical bases of methods of medical imaging and therapy.

Topic 5. Influence of mechanical factors on a living organism.

Specific goals:

- to interpret the biophysical mechanisms of action of ultrasound and infrasound on the human body and to explain the mechanisms underlying the use of ultrasound in medicine;
- explain the effect of vibrations on a living organism.

Ultrasound and infrasound sources and detectors. Parameters of ultrasonic waves. Features of distribution and biophysical bases of action of ultrasound and infrasound on biological fabrics. The use of ultrasound in medicine. Application of ultrasound in dentistry: echoosteometry, Doppler ultrasound.

The effect of vibration on the human body.

Topic 6. Electrodynamics, its medical application.

Specific goals:

- to interpret the genesis of the electrocardiogram on the basis of the analysis of the basic concepts of electrocardiography.
- explain the physical basis of the action of constant and alternating electric fields on the human body and distinguish physiotherapeutic (therapeutic) techniques that use them;
- to analyze the equivalent electrical circuits of biological tissues and blood, the impedance dispersion of biological tissues in normal and pathology;
- to classify electronic medical equipment applied in diagnostics, electrical stimulation and physiotherapy;
- explain magnetic (constant and alternating) and electromagnetic fields affects biological objects, based on the analysis of physical and biophysical processes occurring in biological tissues under the action of physical fields in the human body.
- to make conclusion about the biophysical mechanisms of interaction of electric and magnetic fields with biological tissues.

The concept of electrography of organs and tissues.

Physical and biophysical bases of electrocardiography. Einthoven's first concept of the genesis of the ECG (heart - electric dipole, electric dipole potential, lead system). Ohm's law, electrical conductivity of biological tissues. The second concept of the ECG (heart - current dipole, current dipole potential). Electrography in dentistry.

Physical and biophysical bases of rheography. Dependence between deformation and electrical resistance blood changes of vessels. Vector diagrams and impedance. Capacitive properties and equivalent electrical circuits of biological tissues. Specifics of vector diagrams and impedance of biological tissues. Impedance dispersion coefficient.

Magnetic field and its characteristics. Bio-Savar-Laplace law. Magnetic properties of substances. Physical foundations of magnetobiology. Electromagnetic oscillations and waves in biological media. Offset currents. Maxwell's equation. Wave equations and velocity of propagation of electromagnetic waves in biological objects.

The effect of the electric field on biological tissues. Physical and biophysical processes occurring in biological tissues under the action of constant and alternating electric fields (conduction and displacement currents, thermal effects). Therapeutic factors and their application in medical methods (galvanization, electrophoresis, franklinization, electrostimulation, electropulsation, diathermy, electrotomy, electrocoagulation, etc.).

Effect of constant and alternating magnetic field on biological objects. Primary mechanisms, induction currents, thermal effects. Therapeutic factors and their application in medical methods (magnetic therapy, inductothermy, etc.).

The effect of electromagnetic fields on biological objects. Primary mechanisms, currents and thermal effects, specific action. Therapeutic factors and their use in medical methods (UHF therapy, microwave therapy, microwave resonance therapy, etc.).

Topic 7. Optical methods and their applications in biology and medicine.

Specific goals:

- determine the optical characteristics of the eye and the microscope as a centered optical system;
- interpret the physical mechanisms underlying refractometry and concentration polarimetry;
- demonstrate skills in working with refractometer and polarimeter;
- explain the physical basis of the phenomena of absorption, scattering and dispersion of light;
- explain the methods of concentration colorimetry and nephelometry.

Elements of geometric optics. Centered optical system. Optical microscopy. The main characteristics of the microscope. Techniques of optical microscopy.

Dispersion of light. Refractometry and fiber optics, their use in medicine. The

concept of holography.

Light absorption. Bouguer's law. Absorption of light by solutions, Bouguer-Lambert-Behr law. Concentration colorimetry. Optical properties of biological tissues. Spectroscopy.

Light scattering. Light scattering in dispersion media. Molecular scattering of light. Rayleigh's law. Nephelometry.

Polarization of light. Methods of obtaining polarized light. Double refraction. Nicol prism. Malus law. Optically active substances. Bio Law. Concentration polarimetry.

Topic 8. Elements of quantum biophysics.

Specific goals:

- explain the basic laws of thermal radiation of bodies;
- to interpret the thermal radiation of the human body and the physical foundations of the method of thermography;
- interpret the basic concepts of quantum mechanics;
- to interpret the physical mechanisms underlying the measurement of the size of micro-objects using an electron microscope;
- compare the relevant characteristics of optical and electron microscopes;
- explain the quantum-mechanical model of the hydrogen atom (energy states, quantum numbers, the Pauli principle);
- interpret the main types, properties and applications of luminescence;
- explain the physical basis of the laser and the principle of its operation;
- classify lasers and distinguish areas of laser use in medicine;
- explain the basics of the application of quantum mechanical resonance methods in medicine.

Thermal radiation of bodies, its characteristics. Kirchhoff's law. Laws of radiation of an absolutely black body: Planck's law of radiation, Stefan-Boltzmann's law, Vin's law of displacement. Thermal radiation of the human body. Diagnostic methods: thermoscopy, thermometry, thermography.

Influence of non-ionizing radiation on a living organism. Mechanism of biological action of electromagnetic radiation of ultraviolet, visible, and infrared ranges. Electronic transitions in atoms and molecules. Photochemical reactions. Application of non-ionizing radiation in medicine.

Quantum mechanical model of the hydrogen atom. Quantum numbers. Energy levels. Pauli principle. Radiation and absorption of light by atoms and molecules. Radiation and absorption spectra. Spectrophotometry.

Luminescence. Types of luminescence, main characteristics. Stokes' law. Application of the phenomenon of luminescence in dentistry.

Induced radiation. Equilibrium (Boltzmann) and inverse population of energy levels. Lasers, principle of action and application in medicine and dentistry.

Resonant methods of quantum mechanics. Nuclear magnetic resonance, electronic paramagnetic resonance, their application in medicine (NMR tomography,

etc.).

Topic 9. Radiation biophysics.

Specific goals:

- explain the primary mechanisms of interaction of X-rays with substance and distinguish areas of application of X-rays in medicine;
- analyze the main types, properties and doses of radioactive radiation;
- explain the main mechanisms of interaction of ionizing radiation with biological objects, draw conclusions about ways to protect against the effects of ionizing radiation.

X-rays. Spectrum and characteristics. Primary mechanisms of X-ray interaction with matter. Attenuation and X-rays protection. Application of X-rays in medicine and dentistry for treatment and diagnosis.

Radioactivity, major types of radiation and properties. Radioactive decay law. Half-life. Activity, its units. Ionizing radiation, properties and basic mechanisms of interaction with the biological object. Protection against ionizing radiation. Diagnostic and therapeutic application of radionuclides. Physical and biophysical problems related to the Chernobyl disaster.

Dosimetry of ionizing radiation. Ionizing radiation detectors. Exposure and absorbed doses. Equivalent biological dose. Dose power. Ionizing radiation detectors.

3. Structure of the discipline

Topic	Lectures	Practical (seminar) classes	ISW	Personal tasks
Chapter 1. Biophysics of biological systems				
Topic 1. Thermodynamics of open biological systems. Elements of molecular biophysics.	–	2	4	–
Topic 2. Biophysics of membrane processes	2	4	5	
Topic 3. Fundamentals of biomechanics, bioreology and hemodynamics.	2	10	16	
Topic 4. Biophysics of sensory systems. Biophysics of hearing. Biophysics of the visual analyzer.	2	4	3	–
In total for chapter 1	**6**	**20**	**28**	**–**
Chapter 2. Physical bases of methods of medical imaging and therapy.				
Topic 5. Influence of mechanical factors on a living organism.	–	2	4	–
Topic 6. Electrodynamics, its medical application.	–	8	4	–
Topic 7. Optical methods and their applications in biology and medicine.	–	6	6	–
Topic 8. Elements of quantum biophysics.	–	8	10	–
Topic 9. Radiation biophysics.	2	6	8	–
Final control	–	2	–	**Differential credit**
In total for chapter 2	**2**	**32**	**32**	**–**
Total hours 120 / 4 credits ECTS	**8**	**52**	**60**	**–**

4. Thematic plan of lectures

№	TOPIC	Hours
1.	Cell membranes. Membrane transport. Membrane potentials. The resting potential and the action potential.	2
2.	Mechanical properties of living tissues. Fundamentals of bioreology. Biophysical foundations of hemodynamics.	2
3.	Biophysics of sensory systems. Biophysics of hearing. Biophysics of the visual analyzer.	2
4.	Biological action of ionizing radiation. Dosimetry of ionizing radiation. Applications of ionizing radiation in dentistry.	2
	Total	**8**

5. Thematic plan of laboratory and practical classes

№	TOPIC	Hours
1.	Thermodynamics of equilibrium states.	2
2.	Fundamentals of biophysics of membrane processes. Membrane transport.	2
3.	Membrane potentials. The resting potential. The action potential. Propagation of the action potential in myelinated and non-myelinated nerve fibers.	2
4.	Fundamentals of biomechanics.	2
5.	Biophysics of muscle contraction.	2
6.	Fundamentals of bioreology. Study of rheological properties of biological fluids.	2
7.	Biophysics of the circulatory system.	2
8.	Surface tension of biological fluids.	2
9.	Biophysics of hearing. Sound diagnostic methods.	2
10.	Biophysics of the vision organ. Biophysical bases of visual reception. Devices for research and correction of human vision.	2
11.	Physical bases of ultrasound application in dentistry: echoosteometry, Doppler ultrasonography.	2
12.	Physical bases of electrography of tissues and organs.	2
13.	Direct electric current. Electrical conductivity of cells and tissues. Physical bases of methods of galvanization, electrophoresis.	2
14.	Alternating electric current. Physical bases of rheography. Rheographic methods in dentistry: rheodentography and rheoparodontography.	2

15.	The effect of alternating electric and magnetic fields of high, ultrahigh and ultrahigh frequencies on biological objects. UHF therapy in dentistry.	2
16.	Optical microscopy. Optical microscopy methods in the study of tissue and microorganisms preparations: light microscopy using immersion lenses, dark field, phase contrast, luminescent and other methods of microscopy.	2
17.	Absorption and scattering of light in biological media.	2
18.	Polarization of light. Polarimetry.	2
19.	Thermal radiation. Thermography.	2
20.	Basics applications non-ionizing radiation of ultraviolet, visible and infrared ranges for diagnostics, prevention and treatment in medicine and dentistry.	2
21.	Luminescence. Mechanisms of luminescence. Laws and characteristics of luminescence. Applications in diagnostics.	2
22.	Laser and it applications in dentistry.	2
23.	X-rays. Methods of X-ray diagnostics and X-ray therapy in medicine and dentistry.	2
24.	Radioactivity. Ionizing radiation and its effect on the body. Physical bases of radiodiagnostics and radiotherapy.	2
25.	Dosimetry of ionizing radiation. The effect of ionizing radiation on the body. Quantitative assessment of radio damage. Modification of radiobiological effects.	2
26.	Radiation threats and security in the conditions of martial law Test credit	2
	Total	**52**

6. Thematic plan of individual student's work

№	TOPIC	Hours	Type of control
1.	Thermodynamics of irreversible processes.	4	Current control in practical classes
2.	Physical properties of biological membranes. Liquid crystalline state of biomembranes. Dynamic properties of membranes.	2	
3.	Ion channels of cell membranes. Ionic currents in the axon and methods of their study. Influence of drugs on the value of membrane potential.	3	
4.	Statics. Human musculoskeletal system.	3	
5.	Smooth muscle biophysics. Biomechanics and energy of the heart muscle.	5	
6.	Models of studying blood circulation.	2	

	Measurement of blood flow velocity.		
7.	Blood rheology: parameters, effect on blood flow.	2	
8.	Biomechanics of respiration.	4	
9.	Basic kinematic and dynamic characteristics of mechanical oscillations and waves.	2	
10.	Laws of geometric optics. Refractometry.	1	
11.	The effect of mechanical waves on the body. Principles of ultrasonic imaging. Ultrasonography.	4	
12.	Electrography in dentistry.	2	
13.	Methods of electrotherapy in dentistry.	2	
14.	Methods of optical microscopy in dentistry.	2	
15.	Investigation of optical properties of biological tissues. Spectroscopy.	2	
16.	The wave nature of light. Polarizing microscope.	2	
17.	Temperature topography of the human body.	2	
18.	Chemiluminescence. Application of chemiluminescence in diagnosis.	2	
19.	Laser devices: rules of safe operation. Biological effects of laser radiation on the tissues.	2	
20.	Resonant methods of quantum mechanics. NMR tomography.	4	
21.	X-ray imaging, sources of X-rays. Radiography. Mammography. Angiography. Computed tomography. Save formats and image analysis tools.	4	
22.	Physical principles of radiation therapy.	2	
23.	Nuclear radiation used in medicine.	2	
	Total	**60**	

7. Individual tasks are not implied by the academic program.

8. Teaching methods:

- verbal methods (lecture, conversation);
- visual methods (illustration, demonstration, frontal experiment);
- practical methods (laboratory work and solving problems with professional content);
- individual work of students on comprehension and mastering of material;
- using of computer control and educational programs in the discipline;
- using of the project method to ensure interdisciplinary integration.

9 Control methods

Types of control:

Current control is based on the control of theoretical knowledge, skills and abilities in practical classes. The student's independent work is assessed in practical classes and it is a part of the final assessment of the student.

Final control - differentiated test - is conducted in writing form at the last class (the second semester).

Assessment of current student performance is carried out at each practical (laboratory) lesson on a 4-point scale and is entered in the journal of academic performance. Students' knowledge is assessed from both theoretical and practical training according to the following **criteria**:

- 5 / “excellent” - the student has mastered the theoretical material, demonstrates deep and comprehensive knowledge of the topic or discipline, the main provisions of scientific sources and recommended literature, logically thinks and builds the answer, freely uses the acquired theoretical knowledge in analyzing practical material, expresses his/her attitude to certain problems, demonstrates a high level of mastery of practical skills;

- 4 / “good” - the student has mastered the theoretical material, has the basic aspects of primary sources and recommended literature, studied it; has practical skills, expresses his/her views on certain issues, but assumes certain inaccuracies and errors in the logic of the presentation of theoretical content or in the implementation of practical skills;

- 3 / "satisfactory" - the student has mainly mastered the theoretical knowledge of the subject or discipline, it is guided by primary sources and recommended literature, but unconvincingly answers, confuses concepts, additional questions cause the student uncertainty or lack of stable knowledge; answering questions of a practical nature, reveals inaccuracies in knowledge, is unable to assess facts and phenomena, relate them to future activities, makes mistakes in the implementation of practical skills;

- 2 / "unsatisfactory" - the student has not mastered the study material of the topic (discipline), does not know the scientific facts, definitions, almost does not navigate in the original sources and recommended literature, no scientific thinking, practical skills are not formed.

Assessment of students' knowledge, skills and abilities **at the final control (exam)** is carried out according to the following **criteria**:

Evaluation criteria of theoretical questions	Points
The student sufficiently fully knows the educational material, explains it in a reasoned way, deeply and comprehensively reveals the content of theoretical questions.	6
The student enough fully knows the educational material, explains it in a reasoned way, however permits insignificant inaccuracies during answering.	5
The student enough fully knows the educational material, however does not reproduce it sufficiently justified or mistakes are made.	4
The student does not answer the question fully enough, does not sufficiently justify his/her answer, the sequence of presentation of the material is incorrect, he/she makes mistakes in the use of conceptual apparatus or formulas.	3
The student understands the material only in a general way, the answer is incomplete and shallow; the formulation is not correct enough.	2
The student partially knows the educational material, does not reveal the content of the question, shows unsatisfactory knowledge of the conceptual apparatus.	1
The student does not know the educational material and is not able to explain it, gives the wrong answer to the question or does not answer anything at all.	0

Evaluation criteria of practical skills	Points
The logically correct solution is given. All the key points of the solution are substantiated. Correct answer is received.	5
The logically correct solution is given. Some of the key points of the solution are insufficient. 1–2 minor mistakes in calculations and transformations are possible, which do not affect the correctness of solvution. The received answer may be incorrect or incomplete.	4
The logically correct solution is given. Some of the key points are insufficiently substantiated or not substantiated. 1–2 errors or typos in calculations or transformations are possible, which slightly affect the correctness of solution. The received answer may be incorrect, or incomplete, or only a part of the task is solved correctly.	3
Some steps are omitted in the correct solution. The key points of the solution are not substantiated. Errors in calculations or transformations that affect solution are possible. The received answer is incomplete or incorrect.	2
There are only a few solution steps in the solution. The key points of the solution are not substantiated. The received answer is incorrect or the task is not completely solved.	1
The sotution to the task is not started or the solution is completely incorrect.	0

10. Current control is carried out during training sessions and aims to verify the assimilation of students' learning material.
The form of current control during training sessions is determined by the academic program of the discipline.
Forms of current control are:
1) oral examination (frontal, individual, combined).
2) practical verification of the formed professional skills.
3) test control (open and closed test tasks).
10.1. Evaluation of current educational activities. During the assessment of mastering each topic for the current educational activity of the student grades are set on a 4-point (national) scale. This considers all types of work provided by the discipline program. The current control of the results of the tasks of independent work is carried out during the current control of the topic in the relevant lesson. The student must receive a grade from each topic for further conversion of grades into points on a multi-point (200-point) scale.

11. Form of final control of learning success according to the curriculum is a differentiated credit (the second semester).

Differentiated credit is a form of the final control, which consists in assessing the student's mastery of educational material in the discipline on the basis of the average score of the results of current control and scores for individual control tasks in the final lesson.

Differentiated credit is conduct in writing form according to standardized versions of control tasks, compiled in accordance with the curriculum of the discipline.

The structure of the control task and the evaluation criteria for type each of tasks of differentiated credit:
1) 40 standard test tasks, each of which has one correct answer out of five offered (format A). 40 minutes are allotted for writing the test. (40 points – 1 point for each test task);
2) five open descriptive questions (1 – 5 tasks, 30 points – 6 points for each question) and two problems with professional (medical and biological) content (6 – 7 tasks, 10 points - 5 points for each task). Duration – 95 minutes.

In total – 80 points.

12. The scheme of calculation and distribution of points that are received by students:

Maximum quantity of points, which student can collect for the current educational activity for admission to the exam (differentiated credit) makes 120 points.

Minimum quantity of points, which student can collect for the current educational activity for admission to the exam (differentiated credit) makes 72 points.

The calculation of the number of points is made on the basis of the collected student’s marks on the traditional scale during the discipline study, by calculating the

arithmetic mean (AM or average), rounded to two decimal places. The obtained value is converted into points according to the scoring scale as follows:

$$x = \frac{AM \times 120}{5}.$$

Recalculation of the average score for the current activity in multipoint scale for disciplines ending in an exam (Differential credit)

4- point scale	200-point scale	4-point scale	200-point scale	4-point scale	200-point scale	4-point scale	200-point scale
5	120	4.45	107	3.91	94	3.37	81
4.95	119	4.41	106	3.87	93	3.33	80
4.91	118	4.37	105	3.83	92	3.29	79
4.87	117	4.33	104	3.79	91	3.25	78
4.83	116	4.29	103	3.74	90	3.2	77
4.79	115	4.25	102	3.7	89	3.16	76
4.75	114	4.2	101	3.66	88	3.12	75
4.7	113	4.16	100	3.62	87	3.08	74
4.66	112	4.12	99	3.58	86	3.04	73
4.62	111	4.08	98	3.54	85	3	72
4.58	110	4.04	97	3.49	84	Less than3	Insuffi-ciently
4.54	109	3.99	96	3.45	83		
4.5	108	3.95	95	3.41	82		

Individual work of students is evaluated during the current control of topic on the appropriate class. Mastering topics submitted only for the individual work is controlled at the final control.

Maximum quantity of points, which the student can collect on the differentiated credit is 80 points.

Minimum quantity of points on the differentiated credit is not less than 50.

Point of the discipline, which is completed with an exam is defined as the sum of points for current educational activity (at least 72) and points for the exam (at least 50).

The scores from discipline are converted to the ECTS scale and to the 4-point scale independently. The ECTS scale points are not converted to the 4-point scale and vice versa. Amount of points which is charged to students, from the discipline is converted in scale ECTS thus:

Estimation ECTS	Statistics
A	The best 10 % of students
B	The following 25 % of students
C	The following 30 % of students
D	The following 25 % of students

E	The last10 % of students

"A", "B", "C", "D", "E" ranking is made for students studying at one of the specialties and who have successfully completed study course.

Students who receive grades FX, F ("2") are not included in the list of students ranked. Students with an FX grade automatically receive an "E" score after retaking.

Points of discipline for students who have successfully completed the program are converted into traditional 4-point scale by absolute criteria, which are listed in the following table:

Points from discipline Estimation on 4-point scale	**Points from discipline Estimation on 4-point scale**
From170 to 200 points	5
From140 to 169 points	4
From 139 points to the minimum number of points that student must scores	3
Less than minimal quantity of points, which student must collect	2

The ECTS score is not converted to the traditional scale, as the ECTS scale and the four-point scale are independent. The objectivity of the assessment of students' learning activities is checked by statistical methods (correlation coefficient between ECTS assessment and assessment on a national scale).

13. Methodological support

- Academic program from the discipline.
- Lecture thesis from the discipline.
- Lecture presentations.
- Video content of lectures posted on the Misa distance learning platform.
- Methodical recommendations for teachers.
- Methodical recommendations for practical classes for students.
- Methodical manual for student's independent work.
- Test and control tasks for practical classes.
- Questions and tasks for final control (the differentiated credit).

14. Recommended literature

1. Basic:

1.Chalyi A.V., Tsekhmister Ya.V., Agapov B.T. Medical and Biological Physics: textbook for the students of higher medical institutions of the IV accreditation level. / A.V. Chalyi, Ya.V. Tsekhmister, B.T. Agapov – Vinnytsia, Nova Knyha, 2010. – 480 p.
2.Hobie R.K., Roth B.J. Intermediate Physics for Medicine and Biology. / R.K. Hobie, B.J. Roth. – Springer, 2007. – 616 p.
3.Medical and Biological Physics: Laboratory Manual for students of higher medical

institutions of the IV accreditation level // Lychkovsky E., Fafula R., Fedorovych Z., Makar N., Odnorih L. – Lviv, Danylo Halytsky Lviv National Medical University, 2014. – 300 p.
4. Cotterill R. Biophysics. An introduction. J. Wiley & Sons, 2002. – 396 p.
5. Davidovits P. Physics in biology and medicine. 5-th ed. – Amsterdam: Elsevier Academic Press, 2019. – 377 p.

2. Additional:

1. Medical and biological physics. Practicum for students studying the subject in English / V. M. Trusova et al. - Kharkiv: V. N. Karazin Kharkiv nat. univ., 2018. - 123 p.
2. Newman J. Physics of the Life Sciences. – Springer, 2008. – 718 p.
3. Herman I.P. Physics of the Human Body. – Springer, 2008. – 860 p.
4. Glaser R. Biophysics an introduction. 2-nd ed. – Berlin: Springer, 2012. - 407 p.
5. Hille B. Ionic Channels of Excitable Membranes. Sinauer Associates inc. Sunderland, 2004 - 816 p.

15. Informational resources:

1. http://misa.meduniv.lviv.ua/
2. https://pubmed.ncbi.nlm.nih.gov/ (Electronic database of medical and biological publications in English)
3. http://iomp.org/ (International Organization of Medical Physics)
4. http://aapm.org/default.asp (Website of the American Association of Physicists in Medicine)
5. http://scitation.aip.org/content/aapm/journal/medphys (Medical Physics Journal)