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 222 "Medicine"

Discussed and approved
at the educational-methodical meeting
of the Biophysics department
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Head of the Biophysics department
Prof. Roman FAFULA

Approved
by the Profile Methodical Board
of the Faculty of Foreign Students
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Head of the Methodical Board
of the Faculty of Foreing Students
Assoc. Prof. Tetyana YESHCHENKO

AUTHORS OF THE ACADEMIC PROGRAM OF THE DISCIPLINE:

Roman FAFULA	Professor, Doctor of Biological Science, Head of the Biophysics Department of Danylo Halytsky Lviv National Medical University;
Maria VISTAK	Doctor of Technical Science, Professor of the Biophysics Department of Danylo Halytsky Lviv National Medical University

REVIEWERS:

Zinoviy VOROBETS	Professor, Doctor of Biological Science, Head of the Medical Biology, Parasitology and Genetic Department of Danylo Halytsky Lviv National Medical University;
Oksana BOYKO	Professor, Doctor of Technical Science, Head of the Medical Informatics Department of Danylo Halytsky Lviv National Medical University

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 222 "*Medicine*"
education program *master of medicine*.

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 media, the influence of external factors on the human body, the physical principles of diagnostic and physiotherapeutic methods used in medicine.

"Medical and Biological Physics" is one of the fundamental academic disciplines that make up the theoretical basis of training highly qualified medical specialists. According to the curriculum, the discipline "Medical and Biological Physics" is studied by the first year students. The academic program of the discipline is divided into 2 chapters:

Chapter 1. Biophysics of biological systems.

Chapter 2. The effects of physical factors on a living organism. Physical principles of methods of medical visualization and therapy.

Biothermodynamics, elements of molecular biophysics, biophysics of cellular processes and complex systems, in particular biological membranes, generation of biopotentials, circulatory and respiratory systems, sensory systems, molecular mechanism of cellular processes are studied in chapter 1.

The effects of environmental factors on the human body: mechanical waves, electromagnetic waves of different ranges and parameters, non-ionizing and ionizing radiation are studied in the chapter 2. Physical principles of methods of diagnostics and therapy, medical electronic equipment for visualization, registration and therapy are also studied in chapter 2.

Structure of discipline	The amount of credits, hours including				Year of study, semester	Forms of the control
	In total	Auditorial		Indivi-dual work		
		Lectures	Practical classes			
Discipline "Medical and Biological Physics" ***Chapters – 2***	**4 credits / 120 hours**	**16**	**44**	**60**	**1st year (1st and 2nd semesters)**	**Exam**
by semesters						
Chapter 1	**2.0 credits / 60 hours**	**8**	**22**	**30**	**1st year (1st and 2nd semesters)**	
Chapter 2	**2.0 credits / 60 hours**	**8**	**22**	**30**	**1st year (2nd semester)**	**Exam**

The subject of study of the discipline "Medical and Biological Physics" is the physical processes occurring in biological systems, the influence of external factors on living organisms and the physical principles of diagnostic and physiotherapeutic methods used in medicine.

Interdisciplinary links:

Discipline "Medical and Biological Physics" integrates with the following disciplines:

Medical biology, parasitology, genetics;
Medical chemistry.

Discipline "Medical and Biological Physics" lays the foundations to study following disciplines:

Biological chemistry;
Bioorganic chemistry;
Physiology;
Pathophysiology;
Histology, cytology and embryology;
Medical informatics;
Propaedeutics of internal medicine;
Hygiene and ecology;
Radiology;
Ophthalmology;
Otorhinolaryngology.

1. Objective and tasks of the academic discipline

1.1. The objective of teaching the discipline "Medical and Biological Physics" is to deepen and improve knowledge, skills and practical understanding of biophysical

processes in living organism; physical methods of disease diagnostics and research of biological systems; the impact of physical factors on the human body in treatment; physical properties of materials used in medicine and pharmacy; physical properties and characteristics of the environment.

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

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

1.3. The discipline “Medical and Biological Physics” contributes following **competence and learning outcomes** (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 problems, including those of a research and innovation nature in the field of medicine.

Ability to continue learning with a high degree of autonomy.

– *general:*

GC 1 The ability for abstract thinking, analysis and synthesis.

GC 2 Ability to learn and master modern knowledge.

GC 3 The ability to apply knowledge in practical situations.

GC 4 Knowledge and understanding of the subject area and understanding of the professional activities.

GC 5 Ability to adapt and act in a new situation.

GC 6 Ability to make informed decisions.

GC 7 Ability to work in a team.

GC 8 Interpersonal skills.

GC 9 Ability to communicate in a foreign language.

GC 10 Skills in using information and communication technologies.

GC 11 Ability to search, process and analyze information from various sources.

GC 12 Definiteness and perseverance to the tasks and assumed responsibilities.

- *special (professional):*

PC 2 Ability to determine the required list of laboratory and instrumental studies and evaluate their results.

PC 10 Ability to perform medical procedures.

PC 17 Ability to assess the impact of the environment, socio-economic and biological determinants on the health of the individual, family and population.

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

COMPETENCY MATRIX

No	Competence	Knowledge	Ability	Communication	Autonomy and responsibility
	Integral competence				
	The ability to solve complex problems, including those of a research and innovation nature in the field of medicine. Ability to continue studies with a high degree of autonomy.				
	General competences				
1	Ability for abstract thinking, analysis and synthesis; ability to learn and master modern knowledge.	To know: methods of analysis, synthesis and further modern training.	Be able to: analyze information, make informed decisions, acquire modern knowledge.	Establish appropriate relationships to achieve goals.	To take responsibility for the timely acquisition of modern knowledge.
2	Ability to apply knowledge in practical situations.	To know: specialized conceptual knowledge.	Be able to: solve complex problems and issues 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.	To take responsibility for making decisions in difficult conditions.
3	Knowledge and understanding of the subject area and understanding of the professional activities.	To know: the structure of professional activity.	Be able to: carry out professional activity that needs updating and integration of knowledge.	Ability to effectively form a communication strategy in professional activities.	To take responsibility for professional development, ability to further professional training with a high level of autonomy.
4	Ability to adapt and act in a new situation.	To know: elements of industrial and social adaptation and factors of successful adaptation to a new environment.	Be able to: to form an effective strategy of personal adaptation to new conditions.	Interact with a wide range of people (colleagues, management, specialists from other fields) when new situations with elements of	To take responsibility for making decisions.

				unpredictability arise.	
5	The ability to make informed decisions; to work in a team; interpersonal skills.	To know: tactics and strategies of communication, laws and methods of communicative behavior.	Be able to: make informed decisions, choose methods and strategies of communication to ensure effective teamwork.	Use communication strategies and skills of interpersonal interaction.	To take responsibility for the choice and tactics of the method of communication.
6	Ability to communicate in a foreign language.	To know: one (several) foreign languages.	Be able to: apply knowledge of a foreign language.	Use a foreign language in professional activities.	To take responsibility for using a foreign language in professional activities.
7	Skills in using information and communication technologies.	To know: information and communication technologies used in professional activities.	Be able to: use information and communication technologies in the professional field that needs updating and integration of knowledge.	Use information and communication technologies in professional activity.	To take responsibility for the development of professional knowledge and skills.
8	Ability to search, process and analyze information from various sources.	To know: ways of searching, processing and analyzing information.	Be able to: search, process and analyze information.	Use different methods of information processing.	To take responsibility for information management.
9	Definiteness and perseverance to the tasks and assumed responsibilities.	To know: responsibilities and ways of performing tasks.	Be able to: to determine the goal and task, be persistent and conscientious in the performance of duties.	Set interpersonal communication for effective implementation of tasks and responsibilities.	To take responsibility for qualitative performance of tasks.
	Special (professional) competences				
1	Ability to determine the required list of laboratory and instrumental studies and evaluate their results.	To know: the influence of physical factors on the human body, standard methods of laboratory and instrumental research.	Be able to: analyze research results.	Reasonably select and evaluate research results.	To take responsibility for making a decision regarding the evaluation of research results.
2	Ability to perform medical	To know:	Be able to:	Reasonably form and	Responsibility,

	procedures.	biophysics of human organs and systems.	analyze the biophysical parameters of human organs and systems.	prove conclusions about the need for medical manipulations to the patient and specialists.	independence.
3	Ability to assess the impact of the environment, socio-economic and biological determinants on the health of the individual, family and population.	To know: environmental factors that negatively affect the health of the population.	Be able to: assess the state of the environment and negative factors affecting health.	Make conclusions about the health of the population on the basis of the relationship with environmental factors.	To take responsibility for the correct conclusions regarding the negative impact of environmental factors.

Learning outcomes:
Integrative final program learning outcomes (PLO) of the discipline "Medical and Biological Physics" are:

PLO 1. Have thorough knowledge of the structure of professional activity. To be able to carry out professional activities that require updating and integration of knowledge. To take responsibility for professional development, the ability for further professional training with a high level of autonomy (GC1 – GC12, FC2, FC10, FC17).

PLO 2. Understanding and knowledge of fundamental and clinical biomedical sciences at a level sufficient for solving professional tasks in the field of health care (GC4, GC6, GC10 – GC12, FC2, FC10, FC17).

PLO 3. Specialized conceptual knowledge, which includes scientific achievements in the field of health care and is the basis for research, critical understanding of problems in the field of medicine and related interdisciplinary problems (GC1 – GC3, GC6, GC7, GC9 – CG12, FC2).

PLO 23. Assess the impact of the environment on the state of human health in order to estimate the morbidity pattern of the population (FC17).

PLO 24. Organize the necessary level of individual safety (own and persons cared for) in case of typical dangerous situations in the individual field of activity (CG6).

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

know:

- ✓ general physical and biophysical regularities underlying human life;
- ✓ physical foundations and biophysical mechanisms of external factors effect on human body systems;
- ✓ physical principles of diagnostic and physiotherapeutic (therapeutic) methods used in medical equipment.

able to:

- ✓ analyze physical processes in the body, using physical laws and phenomena;
- ✓ to analyze the mechanisms of interaction of physical factors of the external environment with the human body;
- ✓ demonstrate the ability to choose the method of instrumental research according to the task;
- ✓ demonstrate skills in working with medical equipment used for medical imaging and therapy, including ultrasound diagnostics, electrocardiography, rheography, audiometry, physiotherapy devices, optical and quantum-mechanical devices and systems, radiometric and dosimetric control devices;
- ✓ explain the principle of operation of medical equipment.

2. Information content of academic 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. Biothermodynamics. Elements of molecular biophysics

Specific objectives:

- ✓ to explain the main principles of thermodynamics of open biological systems;
- ✓ to apply the thermodynamic method for studying biomedical systems;
- ✓ to analyze intermolecular interactions in biopolymers;
- ✓ to explain the ordering process in physical, chemical and biomedical systems.

Subject and methods of biophysics, relation with other sciences. Main branches of biophysics. Modern medical biophysics (newest directions of research).

Thermodynamics of equilibrium states. Basic concepts of thermodynamics. The first law of thermodynamics. The main types of work that are carried out in a living organism. Enthalpy. Hess's law. Calorimetry. The second law of thermodynamics. Thermodynamic potentials. Change in standard free energy. Chemical potential. Electrochemical potential. Thermodynamics of biological processes. Temperature homeostasis, chemical and physical thermoregulation.

Thermodynamics of irreversible processes (linear law for the fluxes and thermodynamic forces, cross transfer processes, Onsager reciprocal relations, entropy production, conjugation of flows, steady state, Prigogine theorem).

Intermolecular interaction in biopolymers (covalent interaction, electrostatic and dispersion interaction, hydrophobic interaction, hydrogen bond). Biophysics of proteins. Enzyme catalysis. Biophysics of nucleic acids. Diffusion. Osmotic and oncotic pressure. Basic biophysical research methods of biopolymers. Electrophoresis. Ultracentrifugation. X-ray structural analysis.

Topic 2. Biophysics of membrane processes

Specific objectives:

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

Structure 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: diffusion, osmosis, filtration. Fick's equation. Membrane permeability coefficients for a certain substance. The Nernst-Planck equation. Electrochemical potential. Theorell equation. Primary and secondary active transport. Ion pumps and exchangers. Molecular organization of active transport on the example of Na^+/K^+ pump. Vesicular transport.

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

Action potential. Ionic mechanisms of action potential generation. Propagation of the action potential in nerve fibers. Local potentials. Cable theory. Equivalent electrical diagram of the excitable membrane. Phenomenological Hodgkin-Huxley equations. General principles of functioning of ion channels. Sodium channels. Potassium channels. Calcium channels. Anion channels. Voltage-gated ion channels. The concept of channelopathies.

Topic 3. Fundamentals of biomechanics and bioreology. Biophysics of the circulatory system and breathing

Specific objectives:

- ✓ to interpret basic physical concepts and laws of biomechanics, biorheology and hemodynamics;
- ✓ to explain the mechanical models of the viscoelastic properties of biological tissues;
- ✓ to determine the Young's modulus of biological tissues;
- ✓ to explain phenomena of surface tension and viscosity of fluids;
- ✓ to explain a gas embolism as the physical phenomena;
- ✓ to demonstrate the skills in measuring the surface tension coefficient and the viscosity coefficient of fluids;
- ✓ to explain the physical bases of methods for measuring blood viscosity, blood pressure and blood flow velocity.

Elements of biomechanics. Human musculoskeletal system. Dynamic and statistical work at various types of human activity. Ergometry. Methods and devices for measuring biomechanical characteristics. Mechanical properties of biological tissues. Hooke's law. Young's modulus and Poisson's ratio. Creep and stress relaxation.

Biophysics of muscle contraction. Muscle contraction. Hill's equation. Power of single contraction. Smooth muscle biophysics. Biomechanics and energetics of heart muscle.

Fundamentals of bioreology. Internal friction, viscosity. Newtonian friction law. Newtonian and non-Newtonian fluids. Methods and devices for

measuring viscosity. Rheological properties of blood. Blood viscosity and its use in the diagnosis of diseases.

Surface tension. Surface tension coefficient. Methods of its determination. Surface phenomena in the human body. Gas embolism.

Laminar and turbulent fluid flow. Reynolds number. Basic concepts of hemodynamics. Stationary fluid flow. Continuity equation and Bernoulli's equation. Linear and volume flow rate. Flow of viscous fluids. Poiseuille's Formula and Hagen-Poiseuille formula. Hydraulic resistance. Biophysics of blood circulation. Work and power of the heart. Methods of measuring blood pressure and blood flow rate. Pulse wave. Basic hemodynamic parameters.

Biophysics of breathing. Biomechanics of inhalation and exhalation. Distension of the lungs. Breathing resistance. Work of breathing. Gas exchange. Spirometry. Pneumotachography.

Topic 4. Biophysics of sensory systems

Specific objectives:

- ✓ to interpret basic physical concepts and laws of bioacoustics;
- ✓ to explain the physical foundations of audiometry;
- ✓ to demonstrate skills in working with an audiometer;
- ✓ to explain the physical and biophysical characteristics of the human eye and photoreception mechanisms.

General characteristics and principles of functioning of the sensory system. Research methods of sensor systems. Properties of sensory receptors. Types of receptors and sensations. Classification of sensory receptors and sense organs. Basic biophysical properties of sensory systems and receptors. Biophysical mechanisms of signal conversion in sensory receptors.

Basic characteristics of mechanical vibrations and waves. Mechanism of propagation of acoustic waves. Objective and subjective sound characteristics. Intensity, intensity level, loudness, their units. Hearing threshold and pain threshold. Weber-Fechner law. Biophysics of sound perception. Auditory processes in the outer, middle and inner ear. Impedance matching. Coding of information in the auditory analyzer. Mechanotransduction in hair cells. Physical principles of audiometry. Audiogram and equal loudness curves. Biophysics of voice.

Laws of geometric optics. Basic photometric quantities. Optical power of the eye. Refractive surfaces of the eye. Refractometry. Refraction of the eye in normal and pathological conditions. Accommodation. Aberration. Diffraction. Resolution of the eye. Angle of view. Day and twilight vision. Sensitivity of the eye. Visual defects and their correction. Perception of colors. Spatial vision. Molecular mechanism of visual reception. Transduction processes in retinal photoreceptors.

Biophysics of perception of smell, taste and touch. Structure of receptor molecules. Mechanism of transduction in olfactory neurons and hair cells.

Chapter 2. The effects of physical factors on a living organism. Physical principles of methods of medical visualization and therapy

Topic 5. The influence of mechanical factors on a living organism. Fundamentals of medical equipment. Physical principles of ultrasound diagnostics

Specific objectives:

- ✓ to classify mechanical vibrations and waves;
- ✓ to explain the biophysical mechanisms of action of ultrasound and infrasound on the human body and explain the mechanisms underlying the use of ultrasound in medicine;
- ✓ to explain the physical principles of ultrasonography;
- ✓ to classify electronic medical equipment used in diagnostics, electrical stimulation and physiotherapy.

General characteristics and classification of electronic medical devices. Application of electronic medical equipment in diagnostics and therapy. Electrodes and sensors. Signal amplification and generation. Safety rules when working with electronic medical equipment.

Ultrasound and infrasound. Sources and detectors of ultrasound and infrasound. Peculiarities of propagation and biophysical mechanisms of action of ultrasound on biological tissues. Application of ultrasound in medicine. Lithotripsy. Physical principles of ultrasound diagnostics. Doppler effect. Dopplerography. Effect of infrasound and vibrations on the human body.

Topic 6. Electromagnetic phenomena in biology and medicine

Specific objectives:

- ✓ to interpret the genesis of the electrocardiogram on the analysis of basic concepts of electrocardiography;
- ✓ to explain the physical mechanisms of action of direct and alternating electric fields on the human body and to differentiate physiotherapy (curative) techniques;
- ✓ to analyze the equivalent electrical circuits of biological tissues and blood, dispersions of impedance of biological tissues in healthy and pathological states;
- ✓ to explain the mechanism of direct and alternating magnetic and electromagnetic fields effects on biological objects (based on the analysis of physical and biophysical processes occurr in biological tissues under the influence of physical fields in human body);
- ✓ to draw a conclusion about the biophysical mechanisms of interaction between electric and magnetic fields with biological tissues.

The concept of electrography of organs and tissues. Physical and biophysical principles of electrocardiography. Einthoven's concept of ECG genesis. Electric and current dipole. Leads. Mechanisms of waves formation on ECG. Components of a normal electrocardiogram. Vector electrocardiography. Electric axis of the heart. Physical and biophysical principles of electroencephalography.

Physical and biophysical principles of reography. The relation between the deformation of blood vessels and changes in their electrical resistance. Vector diagrams and impedance. Capacitive properties and equivalent electrical circuit of biological tissues. Specificity of vector diagrams and impedance of biological tissues. The impedance dispersion coefficient.

Effect of electric field on biological tissues. Physical and biophysical processes occurring in biological tissues under the action of a constant and variable electric field (conduction current and displacement current, thermal effects). Healing factors and their use in medical techniques (galvanization, electrophoresis, franklinization, electrostimulation, electric impulsation, diathermy, electrotomy, electrocoagulation, etc.). The mechanism of action of impulse currents on biological tissues. Electrostimulation of organs and tissues. Cardiac pacemakers. Defibrillators.

Magnetic field and its characteristics. Biot-Savart-Laplace-law. Magnetic properties of substances. Physical principles of magnetobiology. Electromagnetic waves and oscillations in biological media. Displacement current. Effect of permanent and variable magnetic field on biological objects. Primary mechanisms, induction currents, thermal effects. Healing factors and their use in medical methods (magnetotherapy, inductothermy, etc.).

Effects of electromagnetic fields on biological objects. Primary mechanisms, currents and thermal effects. Therapeutic factors and their application in medical techniques (UHF-therapy, SHF-therapy, microwave resonance therapy).

Topic 7. Quantum optical phenomena in biology and medicine

Specific objectives:

- ✓ to explain the physical bases of light absorption, scattering, dispersion and polarization;
- ✓ to interpret the physical mechanisms underlying refractometry, photocolorimetry, nephelometry and polarimetry;
- ✓ to demonstrate the skills of working with a colorimeter, a refractometer and a saccharimeter;
- ✓ to explain the mechanisms of action of electromagnetic radiation of the ultraviolet, visible and infrared ranges on a living organism;
- ✓ to explain the basic laws of thermal radiation of bodies;
- ✓ to interpret the thermal radiation of the human body and the physical principles of thermography;
- ✓ to explain the basic concepts of quantum mechanics;
- ✓ to explain the quantum-mechanical model of the hydrogen atom (energy states, quantum numbers, Pauli principle);

- ✓ to explain the physical mechanisms underlying the measurement of microscopic objects by an electron microscope;
- ✓ to compare the characteristics of the optical and the electron microscopes;
- ✓ to explain the main types, properties and application of luminescence;
- ✓ to explain the physical bases of laser and its working principle;
- ✓ to classify lasers and distinguish areas of laser use in medicine;
- ✓ to explain the mechanisms of action of laser radiation on biological tissues;
- ✓ to explain the bases of quantum-mechanical resonance methods in medicine.

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

Light dispersion. Refractometry and fiber optics, their application in medicine. Concept of holography. Endoscopy.

Light absorption. Burger' law. Light absorption by solutions. Burger-Lambert-Beer's law. Concentration colorimetry. Optical properties of biological tissues.

Light scattering. Light scattering in dispersive media. Molecular scattering of light. Rayleigh law. Nephelometry.

Light polarization. Ways to obtain polarized light. Birefringence. Nicholas prism. Malus’ law. Optically active substances. Biot's law. Concentration polarimetry.

Elements of photobiology. The main types and stages of photobiological processes. Electronic transitions in atoms and molecules. Photochemical reactions. The mechanism of biological action of electromagnetic radiation of ultraviolet, visible and infrared ranges on a living organism. Use of non-ionizing radiation in medicine. Photomedicine.

Thermal radiation of bodies, its characteristics. Kirchhoff's law. Laws of radiation of a black body: Planck's law, Stefan-Boltzmann law, Wiens displacement law. Thermal radiation the human body. Diagnostic techniques: thermoscopy, thermometry, thermography.

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

Luminescence. Types of luminescence, basic laws and properties. Stokes' law. Bioluminescence. Chemiluminescence and its diagnostic value. Photoluminescence (fluorescence and phosphorescence).

Phenomenon of photoeffect. External and internal photoelectric effects and their application in medicine.

Stimulated radiation. Equilibrium (Boltzmann) and inversion population of energy levels. Lasers, working principle and application in medicine. Interaction of laser radiation with biological tissues.

Resonance methods of quantum mechanics. Nuclear magnetic resonance, electron paramagnetic resonance, their application in medicine. Nuclear magnetic tomography.

Topic 8. Radiation biophysics. Physical principles of radiation diagnostics and radiation therapy

Specific objectives:

- ✓ to explain the primary mechanisms of interaction of X-rays with matter and to differentiate areas of application of X-rays in medicine;
- ✓ to analyze the main types, properties and doses of radioactive radiation;
- ✓ to explain the basic mechanisms of interaction of ionizing radiation with biological objects, to draw conclusions about the ways of protection against ionizing radiation.

X-rays. Spectrum and characteristics. Primary mechanisms of X-ray interaction with matter. X-ray attenuation and protection against X-rays. Interaction of X-rays with biological tissues. Biomedical application of X-rays (X-ray therapy, X-ray tomography, etc.).

Radioactivity, its types and properties. Radioactive decay law. Lifetime. Activity, units of activity. Biological effect of ionizing radiation: primary physical and chemical processes. Direct and indirect action of ionizing radiation. Modification of radiobiological effects. Diagnostic and therapeutic use of radionuclides. Protection against ionizing radiation. Radioprotectors and radiosensitizers. The physical and biophysical problems related to the Chernobyl disaster: remote effects.

Natural background of radioactivity. Ionizing radiation dosimetry. Exposure and absorbed doses. Equivalent dose. Dose rate. Linear energy transfer. Relative biological efficiency of ionizing radiation. Detectors of ionizing radiation.

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3. Structure of the discipline

TOPIC	Lectures	Practical classes	Individual work	Personal tasks
Chapter 1. Biophysics of biological systems				
Topic 1. Biothermodynamics. Elements of molecular biophysics.	–	4	8	–
Topic 2. Biophysics of membrane processes.	4	4	7	
Topic 3. Fundamentals of biomechanics and bioreology. Biophysics of the circulatory system and breathing.	2	12	9	
Topic 4. Biophysics of sensory systems.	2	4	4	
In total for chapter 1	**8**	**24**	**28**	**–**
Chapter 2. The effects of physical factors on a living organism. Physical principles of methods of medical visualization and therapy				
Topic 5. The influence of mechanical factors on a living organism. Fundamentals of medical equipment. Physical principles of ultrasound diagnostics.	–	2	2	–
Topic 6. Electromagnetic phenomena in biology and medicine.	2	6	2	–
Topic 7. Quantum optical phenomena in biology and medicine.	4	8	20	
Topic 8. Radiation biophysics. Physical principles of radiation diagnostics and radiation therapy.	2	4	8	–
In total for chapter 2	**8**	**20**	**32**	**–**
Total hours 120 / 4 credits ECTS	**16**	**44**	**60**	**–**
Final control				**Exam**

4. Thematic plan of lectures

No	TOPIC	Hours
1.	Cell membranes. Structural and functional organization of membranes. Membrane transport.	2
2.	Resting membrane potential. Mechanisms of action potential generation and propagation. Basic biophysical properties of ion channels.	2
3.	Elements of biomechanics. Biophysical foundations of rheology and hemodynamics.	2
4.	Biophysics of sensory systems. Biophysics of hearing. Biophysics of visual reception.	2
5.	Physical principles of electrocardiography and rheography. Influence of electric and magnetic field on a living organism.	2
6.	Instrumental methods of analysis: optical, spectral and luminescent methods.	2
7.	The effect of ionizing radiation on a living organism. Fundamentals of dosimetry. Physical principles of radiation diagnostics and radiation therapy.	2
8.	Resonance methods of quantum mechanics. Nuclear magnetic resonance, electronic paramagnetic resonance, their application in medicine.	2
	In total	**16**

5. Plan of laboratory and practical classes

No	TOPIC	Hours
1.	Thermodynamics of biological systems.	2
2.	Elements of molecular biophysics. Separate biophysical research methods in medicine.	
3.	Fundamentals of biophysics of membrane processes. Membrane transport.	2
4.	Membrane potentials. Resting membrane potential. Action potential. Propagation of the action potential in myelinated and non-myelinated nerve fibers.	2
5.	Fundamentals of biomechanics.	2
6.	Biophysics of muscle contraction.	2
7.	Fundamentals of bioreology. Study of rheological properties of biological fluids.	2
8.	Surface tension of biological fluids.	2
9.	Biophysics of the circulatory system.	2
10.	Biophysics of breathing.	2
11.	Biophysics of hearing. Sound diagnostic methods.	2
12.	Biophysics of the vision. Biophysical bases of visual perception.	2
13.	Influence of mechanical factors on a living organism. Physical principles of ultrasound diagnostics.	2
14.	Physical principles of electrography of tissues and organs. Electrocardiography.	2
15.	Electrical conductivity of cells and tissues. The effect of electric current on the human body. Physical principles of galvanization, electrophoresis and rheography.	2
16.	The effect of alternating electric and magnetic fields of high, ultrahigh and superhigh frequencies on biological objects.	2
17.	Absorption and scattering of light in biological media. Photocolorimetry and spectrophotometry.	2
18.	Polarization of light. Polarimetry. Polarization microscopy.	2
19.	Thermal radiation. Thermography.	2
20.	Induced radiation. The effect of laser radiation on the living organism and its application in medicine.	2
21.	X-rays. Methods of X-ray diagnostics and X-ray therapy in medicine.	2
22.	Radioactive radiation. The effect of ionizing radiation on a living organism. Dosimetry of ionizing radiation.	2
	In total	**44**

6. Self-study plan

No	TOPIC	Hours	Type of control
1.	Thermodynamics of irreversible processes.	4	Current control during practical classes
2.	Elements of molecular biophysics. Intermolecular interaction in biopolymers. Biophysics of proteins. Enzyme catalysis. Biophysics of nucleic acids.	4	
3.	General principles of functioning of ion channels. The concept of channelopathies.	3	
4.	Ionic currents in the membrane. Hodgkin-Huxley model. Equivalent electrical circuit of the biomembrane. The influence of medicinal substances on the membrane potential.	4	
5.	Statics. Human locomotor system.	3	
6.	Biophysics of smooth muscles. Biomechanics and energetics of heart muscle.	3	
7.	Biophysics of voice.	3	
8.	Basic biophysical properties of sensory systems and receptors. Biophysics of perception of smell, taste and touch.	4	
9.	Basics of medical equipment.	2	
10.	Biomagnetism. Physical foundations of the use of magnetic fields in medicine.	2	
11.	Laws of geometric optics. Refractometry.	2	
12.	Optical microscopy, types of microscopes and their characteristics.	2	
13.	Electron microscopy.	2	
14.	Photobiological processes. Photomedicine.	2	
15.	Phenomenon of photoeffect and luminescence. Application of luminescence in medicine.	4	
16.	Laser devices: rules of safe operation. Biological effects of laser radiation on body tissues.	2	
17.	Resonance methods of quantum mechanics. NMR tomography.	6	
18.	X-ray imaging, sources of X-ray radiation. Radiography. Mammography. Angiography. Computed tomography. Storage formats and image analysis tools.	4	
19.	Methods of radioisotope medicine. Radionuclide diagnosis Positron emission tomography.	2	
20.	Nuclear safety. Protection against ionizing radiation.	2	
	In total	**60**	

7. Individual tasks are not provided in the curriculum.

8. Teaching methods:

- ✓ verbal methods (lecture, discussion);
- ✓ visual methods (illustration, demonstration, frontal experiment);
- ✓ practical methods (laboratory work and solving of problems with professional content);
- ✓ individual work of students with comprehension and learning of material;
- ✓ use of control and training computer software;
- ✓ use of project method for interdisciplinary integration.

9. Control methods:

Types of control:

- ✓ Current control is realized on the basis of control of theoretical knowledge, skills and abilities in practical classes.
- ✓ Final control (examination) is realized in the form of a written exam (the second semester).

Assessment of students' current performance is realized at each practical (laboratory) class by a 4-point scale and is recorded in the student progress journal. Students' knowledge is assessed on both theoretical and practical training according to the following **criteria**:

- ✓ grade 5/"excellent" – the student has mastered the theory flawlessly, demonstrates deep and comprehensive knowledge of the certain topic or academic discipline, the main theses of scientific papers and recommended literature, thinks logically and gives an answer, freely uses the acquired theoretical knowledge when analyzing practical material, expresses his attitude to certain problems, demonstrates a high level of mastery of practical skills;
- ✓ grade 4/"good" – the student has mastered the theoretical material well, knows the main aspects from primary sources and recommended literature, presents it in a reasoned way; has practical skills, expresses his thoughts on certain issues, but certain inaccuracies and errors are assumed in the logic of the presentation of theoretical content or in the performance of practical skills;
- ✓ grade 3/"satisfactory" – the student has basically mastered the theoretical knowledge of the topic or discipline, orients himself in primary sources and recommended literature, but answers unconvincingly, confuses concepts, additional questions cause the student uncertainty or lack of stable knowledge; when answering questions of a practical nature, reveals inaccuracies in knowledge, does not know how to evaluate facts and phenomena, relate them with future activities, makes mistakes when performing practical skills;
- ✓ grade 2/"unsatisfactory" – the student has not mastered the material of the topic (discipline), does not know scientific facts, definitions, hardly orients himself in primary sources and recommended literature, lacks 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 realized during classes and aims to examine the students' mastery of learning material.

Forms of current control:

1) oral examination (frontal, individual, combined examination);
2) practical verification of the formed professional skills;
3) test control (open and closed tests).

10.1. Evaluation of current educational activity. In evaluating the mastering of each

topic for current educational activity the students get grades in the 4-point scale (traditional scale). All types of work provided by the academic program are taken into account. The student's individual work is evaluated during practical classes. The student gets a grade on each topic for further conversion of grades into points by multipoint (200-point) scale.

11. Form of the final control is examination (second semester) according to the curriculum.

Examination (exam) is a form of final control of the student's mastery of theoretical and practical material on the academic discipline. The exam takes place in written form by examination papers in accordance with the academic program. The exam is written and includes both theoretical and practical training.

The structure of the examination papers and the evaluation criteria for each type of exam tasks:

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 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

Maximum score points which a student can obtain for the current educational activity for admission to the exam is 120 points.

Minimum score points which a student must obtain for the current educational activity for admission to the exam is 72 points.

Calculation of score points is based on grades received by student in the 4-point scale (traditional scale) (by calculation of the arithmetic mean (*AM*) rounded to two decimal places). The resulting value is converted into points by multi-points scale as follows:

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

For convenience, a table of conversion into 200-point scale is given:

Conversion of the average grade for current educational activity to the point scale for discipline which is finished with exam

4-grade scale	200-grade scale	4-grade scale	200-grade scale	4-grade scale	200-grade scale	4-grade scale	200-grade 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 than 3	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 score points which a student can score in exam is 80.

Minimum score points required for passing is not less than 50.

Grade on discipline is calculated as the sum of score points for current educational activity (at least 72 points) and score points for the exam (at least 50 points).

Points on discipline are converted regardless both in ECTS scale and a 4-point scale (traditional scale). Scores of ECTS scale can not be converted into 4-point scale and vice versa. Score points of students studying in one specialty are ranked on the ECTS scale as follows

Grade in ECTS	Statistical index
A	Top 10% of students
B	The next 25% of students
C	The next 30% of students
D	The next 25% of students
E	The last 10% of students

Ranking with assigning grades of “A”, “B”, “C”, “D”, “E” is held for the students of one course, studying one specialty and successfully completed the academic discipline. Students who have received grades FX, F (“2”) are not recorded to the list of students for ranking. Students who have received grade FX after repassing get grade “E” automatically.

For students who completed the program successfully the points on discipline are converted into a traditional 4-point scale by absolute criteria, which are listed in the table below:

Points on discipline	Grade in 4-point scale
From 170 to 200 points	5
From 140 to 169 points	4
From 139 to minimum score points	3
Lower than to minimum score points	2

The ECTS score is not converted to the traditional scale, as the ECTS scale and the 4-point scale are independent. The objectivity of the assessment of students' learning activities is checked by statistical methods (correlation coefficient between grade in ECTS scale and grade in national scale).

13. Methodical providing:

- ✓ academic program of the discipline;
- ✓ lecture notes on discipline (thesis);
- ✓ lecture presentations;
- ✓ video content of lectures on the distance learning platform;
- ✓ guidelines for lecturers/instructors;
- ✓ guidelines for practical classes for students;
- ✓ guidelines for individual students' work;
- ✓ test and control tasks for practical classes;
- ✓ questions and tasks for the final control (exam).

14. List of recommended literature

Main sources:

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. – Vinnytsia, Nova Knyha, 2010. – 480 p.
2. Davidovits P. Physics in biology and medicine. 5th ed. – Amsterdam: Elsevier Academic Press, 2019. – 377 p.
3. Herman I.P. Physics of the Human Body. Springer, 2008. – 860 p.
4. Hobie R.K., Roth B.J. Intermediate Physics for Medicine and Biology. Springer, 2007. – 616 p.
5. 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.
6. Newman J. Physics of the Life Sciences. Springer, 2008. – 718 p.

Additional sources:

1. Cotterill R. Biophysics. An introduction. J. Wiley & Sons, 2002. – 396 p.
2. Glaser R., Biophysics, Springer, 2004.

3. Hendee W., Ritenour R. Medical imaging physics. J.Wiley&Sons, 2002.

15. Information resources

1. http://misa.meduniv.lviv.ua/(Distance learning platform of Danylo Halytsky Lviv National Medical University)
2. https://pubmed.ncbi.nlm.nih.gov/ (Electronic database of medical and biological publications)
3. https://www.biophysics.org/ (Biophysical Society)
4. http://iomp.org/ (International Organization of Medical Physics)
5. http://aapm.org/default.asp (Website of the American Association of Physicists in Medicine)
6. http://scitation.aip.org/content/aapm/journal/medphys (Medical Physics Journal)
7. https://physicsworld.com/c/biophysics-bioengineering/ (Information resources on biophysics and bioengineering)
8. https://physicsworld.com/c/medical-physics (Information resources on medical and bioengineering)