

Elective Course “Medical Equipment: Physical and Biophysical Principles”

Alexander Chalyi*, Victoria Pashchenko, Kyrylo Chalyy, Natalia Stuchinska, Anatoly Egorenkov, Larisa Lesko, Jury Litvin and Victoria Rudneva

Department of Medical and Biological Physics and Informatics, Bogomolets National Medical University, Kyiv, Ukraine

***Corresponding Author:** Alexander Chalyi, Professor, Head of Department of Medical and Biological Physics and Informatics, Bogomolets National Medical University, Kyiv, Ukraine.

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Abstract

The main goal of the elective course “Medical Equipment: Physical and Biophysical Principles” is the formation of a knowledge system among students of Higher Medical Institutions about the physical and biophysical principles of operation of medical equipment used in modern medicine for therapeutic and diagnostic purposes; mastering basic modern physical principles study of living nature processes; the application of statistical methods for the analysis and interpretation of the obtained results of biomedical research, which form the basis of subject competencies in medical and biological physics and are an integral component of the professional competence of a future specialist in the field of health care. The main structure of the program of this discipline is considered. It should be noted that the programs of the elective course “Medical Equipment: Physical and Biophysical Principles” are partially profiled for three different specialties “Medicine”, “Pediatrics” and “Dentistry”.

Keywords: *Medical Equipment; Biomechanics; Functional Diagnostics; Thermography; Nuclear Medicine; Radiation Therapy; Physiotherapy*

Introduction

The elective course «Medical Equipment: Physical and Biophysical Principles» forms and gives the following necessary knowledge, skills and competences for students of Higher Medical Institutions, who are preparing at the magister’s level in the field of knowledge «Health Care» for three specialties «Medicine», «Pediatrics» and «Dentistry»:

- Physical and biophysical principles that form the basis of medical equipment used in modern methods of diagnosis and treatment;
- The mechanisms of action of external fields on the human body, which are the basis of modern physiotherapeutic equipment and determine the main principles of its work and application for various medical specialties;
- General physical and biophysical regularities, which are the basis of methods of measuring biophysical characteristics of tissues and parameters of physiological processes in the human body for the purpose of their diagnosis and monitoring;
- Physical and mechanical regularities of the structure and functioning of the human musculoskeletal system, as well as the diagnostic and rehabilitation methods;
- Physical and biophysical principles underlying respiratory mechanics, diagnostic and monitoring methods;

- Formation of the necessary knowledge, skills and abilities to carry out the procedure;
- functional research using profile diagnostic medical equipment in further professional activity;
- The basics of dosimetry and principles of radiation safety when carrying out activities with using modern medical equipment for radiation diagnostics and treatment;
- Mastering the physical basics of radiation therapy methods, principles dosimetric planning of radiation therapy.

The lecture course of the elective discipline “Medical Equipment: Physical and Biophysical Principles” is accompanied by practical and laboratory classes that provide students with additional competencies and practical skills, in particular, measuring individual parameters of biological systems using medical equipment; verification and assessment of measurement errors, interpretation of biophysical characteristics; as well as use of modern medical equipment. The list of recommended textbooks, monographs, training manuals and scientific articles [1-14] is given in the “Bibliography” section.

In accordance with the approved curriculum, the elective course “Medical Equipment: Physical and Biophysical Principles” provides interdisciplinary connections and integrates with the following educational disciplines: “Medical and Biological Physics”, “Medical Biology”, “Medical Chemistry”, “Biological and Bioorganic Chemistry”, “Human anatomy”, “Physiology”, “Clinical Anatomy and Operative Surgery”, “Hygiene and Ecology”, “Anesthesiology and Intensive Care”, “Ophthalmology”, “Radiology and Radiation Medicine”, “Palliative and Hospice Medicine”, “Physical Rehabilitation, Sports Medicine”, etc.

Taking into account the requirements of the educational and professional programs for knowledge, skills and competencies, the expected results of students’ studying the elective course «Medical Equipment: Physical and Biophysical Principles» should be as follows.

Know:

- General physical and biophysical laws that are the basis of the processes occurring in the human body;
- General physical and biophysical laws that are the basis of the methods of (invasive and non-invasive) measurement of biophysical characteristics of tissues and parameters of physiological processes in the human body for the purpose of diagnosis and monitoring;
- Characteristics of physical external factors affecting the human body, and biophysical mechanisms of these effects;
- Purpose and principle of operation of modern physiotherapeutic equipment;
- Purpose and principles of operation of modern medical equipment for diagnostics and treatment, metrological parameters of modern medical equipment, safety techniques when working with it;
- Basics of dosimetry and principles of radiation safety in modern methods radiation diagnostics and treatment;
- Basics of biomechanics and methods of mechanotherapy;
- Basics of respiratory mechanics and methods of functional diagnostics respiratory organs;
- Basics of blood pressure measurement methods by various methods;
- Basics of thermography and methods of thermometry;

- Basics of operation of devices for measuring hematological characteristics;
- Basics of methods of mathematical processing of medical and biological data;
- Physical foundations of radiation therapy methods, principles of dosimetry planning of radiation therapy;
- Basics and physical principles of radiation and nuclear diagnostics medicine, in particular: magnetic resonance imaging (MRI), positron-emission tomography (PET), computer tomography (CT), and combined PET/CT, PET/MRI technique.

Able to demonstrate:

- Knowledge sufficient to understand basic physical and biophysical processes, which are the basis of modern methods of diagnosis and treatment;
- Understanding of the processes occurring in the human body under the influence of physical factors, general physical and biophysical regularities that form the basis of methods for measuring biophysical characteristics of tissues and parameters of physiological processes in the human body for the purpose of diagnosis and monitoring; practical skills of working with medical devices;
- Understanding of the functional relationship between various physical parameters, which are measured by medical diagnostic devices and physiological processes that generate these parameters;
- Knowledge and understanding of the principle schemes of the studied medical devices;
- Knowledge and understanding of the physical principles of operation of medical devices used in radiation therapy;
- The ability to reasonably determine the expediency of using methods radiation diagnostics and nuclear medicine, in particular: magnetic resonance tomography (MRI), positron emission tomography (PET) and combined PET/MRI techniques.

Have the skills to:

- Conducting laboratory research; registration, measurement, analysis and interpretation of medical and biological research data with the help of appropriate methods and technical means;
- Assessment of measurement errors of biophysical characteristics;
- Analysis of the effects of physical factors on the human body when using certain medical equipment for the purpose of treatment, prevention and rehabilitation of the patient;
- Evaluate the radiological impact of ionizing radiation with taking into account their distribution in time and space;
- Justification of the expediency of using the methods of radiation diagnostics and nuclear medicine, in particular: magnetic resonance imaging (MRI), positron-emission tomography (PET) and combined PET/CT, PET/MRI technique.

To consider and decide independently:

- Typical tasks in the process of further education with using modern physical and biophysical principles and research methods.

Basic structure of the elective course “medical equipment: Physical and biophysical principles”

Let us dwell in more detail on the main topics of lectures and practical (laboratory) classes of the elective course «Medical equipment: Physical and biophysical principles».

Topic 1: Biomechanics of the musculoskeletal system. Physical foundations densiometry and tensometry

- In this section, questions related to the structure and functions of the biomechanical system of the human musculoskeletal system (HMSS) are considered, in particular the passive and active parts of the HMSS.
- Basic concepts and laws of biorheology and biomechanics are considered, which are used to describe the functioning of HMSS.
- Modern biophysical principles of the mechanical properties of biological tissues are presented, which are parts of HMSS (bones, muscles, tendons, joints, etc).
- Special attention is paid to the biomechanical characteristics of human movements and the calculation of kinematic characteristics of the human body and its movements. At the same time, the model of the human kinematic scheme is used.

Topic 2: Physical foundations of respiratory mechanics and methods of functional diagnostics. Spirometry, principles of operation of the apparatus for artificial lung ventilation

- The purpose of studying the topic is to form a system of theoretical knowledge, skills and abilities regarding the basics of respiratory mechanics, methods of functional diagnostics of respiratory organs and physical principles of operation of the apparatus for artificial lung ventilation.
- General physical and biological regularities of the breathing process.
- Students are studying the principles and basic modes of the apparatus for artificial lung ventilation, the diagnostic and therapeutic value of static and dynamic indicators of pulmonary ventilation.
- An important feature of this topic is the development of skills in the analysis and interpretation of medical and biological research data and the solution of respiratory mechanics problems.

Topic 3: Physical foundations of thermography, tonometry. Physical principles the work of hematological analyzers

- The physical foundations of the processes underlying the methods of thermography, tonometry and hematological measurements have been analyzed.
- The thermal radiation laws, its quantitative characteristics and physical principles of operation of non-contact thermometers are considered.
- The classification of modern tonometers for measuring human blood pressure, algorithms for measuring blood pressure by auscultatory and oscillatory methods are discussed.
- The physical principles of operation of a modern automatic hematology analyzer, as well as the principles of operation of photocolometric medical equipment are studied.

Topic 4: Physical foundations of radiation diagnostics and nuclear medicine (MRI, PET, CT and PET/CT, PET/MRI)

- This topic is dedicated to explaining (at a level that is accessible to students - future doctors) the outstanding achievements of quantum mechanics and quantum electrodynamics that have created powerful and precise methods of radiation diagnostics and nuclear medicine, which have found their wide use in medical practice. Here, we are going to explain the main problems as follows:
 - The phenomenon of nuclear magnetic resonance (Nobel Prize in Physics). Radio frequency pulse, relaxation and formation of spin echo.
 - General principles of magnetic resonance imaging (MRI): Types of magnets, magnetic gradients, radio frequency system (Nobel Prize in Physiology or Medicine). Pulse sequences and tissue contrast. Image quality: factors affecting signal-to-noise ratio, scan time. Spatial resolution. Bioeffects and safety.
 - The general principle of positron emission tomography (PET): Decay of radionuclides, the process of annihilation of electrons and positrons with the emission of photons. Photon detectors, scintillation detectors. Image reconstruction. PET, PET/CT and PET/MRI scanner design.
 - At lectures and practical classes, students receive the necessary theoretical information and understanding of the physical basis of the appearance of X-ray images, as well as the use of computed tomography (CT), magnetic resonance imaging (MRI), positron-emission tomography (PET) in the context of diagnostic radiology.

Topic 5: Physical foundations of radiation therapy

- Today, radiation therapy is one of the most effective methods of treatment in the arsenal of means of combating neoplasms.
- The primary mechanisms of interaction of ionizing radiation with biological tissues are described by the laws of physics. The processes of energy absorption, excitation and ionization of atoms and molecules are a trigger for the emergence of secondary processes that develop according to biological and biochemical laws, causing structural, functional and metabolic changes in living organisms.
- The basic principle of radiation therapy is to deliver the optimal radiation dose to the pathological focus with minimal damage to normal tissues located in the radiation zone.
- Planning treatment tactics involves: justified choice of species irradiation; calculation of the optimal radiation dose; definition mode and technology of irradiation - you will find consideration of these issues in lectures and practical classes on this topic.

Topic 6: Physical foundations of physiotherapy: mechanisms of action of electric, magnetic and electromagnetic fields on biological tissues

- One of the most important areas of modern physiotherapy is the use of conduction currents, induction currents and bias currents, as well as thermal effects created, accordingly, by electric, magnetic and electromagnetic fields under their interaction with biological tissues of the human body.
- Physico-chemical transformations, occurring in biological tissues as a result of the action of these physical factors, affect the biochemical and physiological processes in the human body, being widely used for therapeutic, preventive, diagnostic and rehabilitation purposes.

- The analysis of physical and biological processes occurring in biological tissues under the influence of physical factors is provided.
- The basic methods of physiotherapeutic procedures used in clinical and rehabilitation medical institutions for the treatment of various diseases are considered.

Conclusion

The importance of deep knowledge and skills that graduates of higher medical educational institutions should have in the field of using modern medical equipment for health care is difficult to overestimate. In practical terms, medical and biological physics, as well as biomedical engineering and medical informatics are integral parts of the modern medicine and medical education. It is these sections of science and technology and educational disciplines that have provided a reliable foundation for the creation of precision and high-tech medical equipment for diagnostics and treatment, starting from X-ray and cardiography devices and ending (so far!) with the da Vinci surgical robotic system for minimally invasive interventions, as well as a Philips Healthcare spiral CT scanner and combined medical imaging systems PET/CT, PET/MRI. And then continuing with everything that physicists, engineers and IT specialists, certainly together with doctors, will definitely invent and apply for the medicine of the future.

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