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IMPROVING THE TEACHING OF PHYSICS BASED ON ITS INTEGRATION WITH BIOPHYSICS AND MEDICAL SCIENCES

Usmonov Saidjon Abdusubxon o‘g‘li
Teacher of the Department “Biomedical Engineering, Biophysics, and Information Technology,” Fergana Institute of Public Health Medicine
Gmail: usmonovsaid@gmail.com

Abstract
In the current credit-module system, the educational direction 60711100 – Biomedical Engineering allocates 10 credits to the physics course. The total number of hours assigned to this subject is 300, with 60 hours for lectures, 30 hours for practical sessions, 30 hours for laboratory work, and 180 hours for independent study. It is evident that the hours allocated for independent study significantly exceed those for lectures, practical sessions, and laboratory work combined. This means that a large volume of information must be delivered to students within a limited timeframe, especially since the hours allocated for classroom activities have been reduced compared to previous systems. How can this issue be addressed? In our view, the most effective solution lies in properly and efficiently organizing both classroom activities and independent study. It is crucial to consider the future specialization of students, ensuring interdisciplinary integration.

Keywords: Building “bridge” relationships between disciplines, ensuring interdisciplinary integration, professional and general competencies, integration of biomedical engineering disciplines, biomedical engineer.

INTRODUCTION

Modern medicine places increasing demands on the quality of education, which in turn heightens the competition among graduates of higher education institutions, including medical ones, by emphasizing the competence and professional preparedness of future specialists. The successful implementation of their skills requires readiness and capability, aiming to enhance the efficiency and quality of their professional activities.

Realizing such goals involves comprehensive preparation, shaping and developing the personality of modern individuals as professionals, as well as members of society and teams. This process relies solely on a competency-based approach, targeting professional competencies and educational content. To achieve the objectives of forming students’ professional competencies through interdisciplinary integration, university professors must systematically undertake this effort. This requires planning binary (dual) and integrated lectures within educational programs, involving instructors from various departments, disciplines, and cycles to deliver lecture materials, and incorporating “bridge” relationships between different fields.

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Methods:

The State Educational Standard defines professional and general competencies—i.e., the knowledge, skills, and qualifications that graduates must acquire. These can be achieved through an integrative approach in designing core professional education programs. Integrative education plays a critical role in shaping the professional competencies of future specialists and preparing them for their future careers. Table 1 below presents the key physical concepts that facilitate the integration of physics with biomedical engineering disciplines in medical higher education institutions.

Table 1: Integration of Physics with Biomedical Engineering Disciplines

Biomedical Engineering Discipline	**Concepts Facilitating Integration of Physics and Biomedical Engineering**
Biophysics	Deformation, Elasticity, Young's Modulus, Mechanical Stress, Fluidity, Collagen, Strength Limit, Intensity, Noise, Percussion, Auscultation, Sound Spectrum, Acoustics, Ultrasound, Infrasound, Laminar Flow, Turbulent Flow, Viscosity, Viscometer, Diffusion, Biopotential, Rheobase, Hysteresis, Fluorography, Accommodation, Nitrogen.
Higher Mathematics	Vectors, Abscissa, Ordinate, Applicata, Axiom, Algorithm, Analysis, Integral, Derivative, Argument, Schrödinger Equation, Graph, Euclidean Space, Collinear Vectors, Canonical Equation, Limit, Radius, Cramer's Method.
Metrology and Standardization	All measurement quantities in the International System of Units, All types of measuring instruments, Scale, Micrometer, Photodensitometer, Absolute Error, Relative Error, Standard, Force, Gravitational Force, Frequency, Sensitivity Range, Efficiency Coefficient, Archimedes' Principle, Electromagnetic Induction, Elastic Force, Ohm's Law, Electrical Resistance.
Electrical Engineering and Electronics	Dielectric Conductivity, Dielectric Polarization, Dielectric Absorption, Electric Field Strength, Ferrites, Photoelements and Batteries, Non-metallic Conductors, Liquid Crystals, Semiconductors, Piezoelectrics.
Theoretical Mechanics	Absolute Rigid Body, Velocity Graph, Moment of Force, Acceleration, Inertia, Angular Momentum, Reaction Force, Steiner's Theorem, Classical Mechanics, Lever, Pulleys, Golden Rule of Mechanics, Lever Equilibrium Conditions, Material Point, Force Arm, Center of Mass, Dynamics Principles, Friction Force.
Medical Devices and Service	Ultrasound, Infrasound, Doppler Effect, Optical Quantum Generator, Photoeffect, X-rays, Lasers, Spontaneous Emission, Photoelectron Emission, Polarizers, Electrolysis Laws, Faraday's Laws, Specific Heat Capacity, Pressure, Atmospheric Pressure, Resonance, Decibels, Weber-Fechner Law, Dosimetry, Radioactivity, Electron Paramagnetic Resonance.
Biomedical Signal Processing	Signals, Amplitude, Pulse, Spectral Density, Aberration, Diamagnetics, Curie Point, Photoelectron Emission, Wavelength, Huygens' Principle, Electromagnetic Wave.
Biomedical Sensors	Potential Difference, Light Absorption, Thermal Conductivity, Fourier Analysis, Photodetectors, Snell's Law, Lambert-Beer Law, Planck's Law, Entropy, Wave Equation, Frequency Spectrum, Thermocouples and Infrared Sensors, Positron Emission Tomography, Ionizing Radiation.
Electromagnetism in Medicine	Magnetic Field Induction, Biot-Savart-Laplace Law, Lorentz Force, Hall Effect, Magnetic Field Strength, Landé Factor, Ferromagnetics, Diamagnetics, Paramagnetics, Curie Point, Solar Magnetosphere, Magnetic Permeability of Medium.
Biomedical Optics	Geometric Optics, Quantum Optics, Law of Refraction, Total Internal Reflection, Lenses, Spectrophotometry, Laser, Image Formation in Lenses, Dispersion, Photometry, Optical Power, Bouguer's Law, Interference, X-rays, Polarization, Absolute Refractive Index of Medium, Light Intensity.
Biomechanics	Mechanical Motion, Reference System, Kinematics, Support Reaction Forces, Kinetic Energy, Deformation, Young's Modulus, Mechanical Stress, Archimedes' Principle, Moment of Force, Lever Equilibrium Condition, Power, Dynamics Laws, Angular Acceleration, Load, Body Weight, Translational Motion, Inertial Force, Moment of Inertia.
Biomedical Circuits	Resistors, Capacitors, Diodes, Inductors, Kirchhoff's Laws, Ohm's Laws, Transformers, Zener Diodes, Varicaps, Transistors, Thyristors, Semiconductor Photoresistors, Direct Current, Alternating Current.

Students in the Biomedical Engineering program (60711100) at medical higher education institutions are required to master subjects such as electrical engineering and electronics, biomedical circuits, mechanics and electronics, biomechanics, biomedical optics, electromagnetism in medicine, medical device service, metrology and standardization, biophysics, and theoretical mechanics over four years. According to the current curriculum, a total of 6,180 hours is allocated, of which 3,840 hours (62.1%) are directly related to or built upon physics. Thus, a solid foundation in physics is essential for mastering these subjects, as understanding basic physical laws and principles is critical to explaining the physical phenomena and processes occurring in the human body and medical devices.

For instance, let us consider the "Medical Devices" module, one of the most important general professional modules in the Biomedical Engineering curriculum:

The teaching of the "Medical Devices" module relies on students' prior knowledge and skills acquired from modules such as physics, biophysics, information technology in medicine, descriptive geometry, and engineering graphics. It equips future biomedical engineers with the ability to use medical technology and devices to diagnose organs and systems, treat conditions, interpret medical data accurately, and foster clinical reasoning in general practitioners by identifying and justifying diseases and their symptoms.

Objectives and Tasks of the Module:

1. Objective: To instill in future specialists theoretical and practical knowledge about the structure, operating principles, and applications of medical instruments, equipment, and devices used in diagnostic methods for correctly interpreting physiological processes in organs and systems. Additionally, to teach students how to operate recording, diagnostic, and therapeutic medical devices, as well as instruments for measuring external environmental impacts (dosimetric) and protective equipment.

2. Tasks:

- Study the structure, functions, and operating principles of medical instruments used for diagnostics, treatment, and scientific research.
- Explore the mechanisms of interaction between physical factors (energy carriers) in medical devices and organs/tissues.
- Master the general principles of structuring treatment technology systems in medical institutions.
- Learn to select appropriate medical instruments and equipment for specific diagnostic and therapeutic purposes.
- Understand technical documentation, structure, and operating principles of medical devices proficiently while adhering to safety regulations.

3. Requirements for Students' Knowledge, Skills, and Competencies:

- Understand the basics of the structure, functions, and operating principles of medical instruments used in diagnostics, treatment, and research.

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○ Comprehend the mechanisms of interaction between physical factors in medical devices and organs/tissues, the general principles of treatment technology systems in specialized clinics, and how to select appropriate medical instruments for specific diagnostics and treatments.

○ Be proficient in interpreting technical documentation, understanding device structure and principles, adhering to safety protocols, operating devices used in treatment, diagnostics, surgery, and resuscitation, and documenting medical data.

○ Apply physical laws to processes in living organisms.

○ Acquire practical skills in obtaining, recording, and analyzing medical-biological data using physical-technical instruments and equipment.

Results:

Teaching physics, biophysics, and medical sciences through an integrated approach is increasingly vital due to the growing demands of modern medicine and science. Understanding the interconnectedness of these fields is essential for young specialists to develop innovative solutions, identify and solve clinical problems, and work with advanced medical technologies. Below are key proposals for improving education in this direction:

- **Developing Integrated Curricula**: Creating specialized programs that highlight the connections between physics, biophysics, and medicine, enabling students to apply theoretical knowledge practically.
- **Updating Modules and Practical Sessions**: Incorporating exercises on the application of physics and biophysics in medicine to enhance practical skills, using dedicated labs, simulation platforms, and medical technologies.
- **Collaboration with Experts**: Organizing seminars, workshops, and masterclasses with practicing biophysicists and medical professionals to provide students with real-world examples and experiences.
- **Fostering Analytical and Research Skills**: Teaching research methods and encouraging students to conduct their own scientific projects to develop critical thinking, boosting confidence in future scientific and practical endeavors.
- **Utilizing Interactive and Digital Technologies**: Leveraging online platforms, simulations, virtual labs, and e-learning materials to allow students to explore scenarios and deepen their understanding of interdisciplinary integration.

Teaching physics, biophysics, and medical sciences in an integrated manner equips students with the skills and knowledge necessary for successful careers in modern medicine, enhancing their qualifications and improving healthcare quality.

Discussion

Table 2 below outlines the objectives of teaching medical and engineering disciplines, along with improved topics that facilitate the integration of physics into medical technology disciplines:

Table 2: Objectives and Improved Topics for Integrating Physics into Medical and Engineering Disciplines

№	Medical and Engineering Discipline	Objective of Teaching	Improved Topics Facilitating Integration of Physics
1	Biophysics	To instill theoretical and practical knowledge for interpreting physiological processes in organs and systems, demonstrating the primacy of physical changes in disease processes.	Determining the internal friction coefficient of liquids using Stokes' method (laboratory). Studying Young's modulus of elastic bodies. Determining microscope magnification and refractive indices of optically transparent materials.
2	Electrical Engineering and Electronics	Basics of electrical engineering and measurement laws; designing and calculating DC circuits; analyzing AC circuits; performing measurements with instruments (e.g., ammeter, voltmeter); understanding rectifiers' structure, principles, and applications; adhering to safety and measurement standards.	Measuring small resistances and determining specific resistance of conductors. Studying parallel and series connections of conductors. Investigating one-way conductivity of semiconductor diodes.
3	Medical Devices and Service	To develop knowledge, skills, and competencies in providing electronic service for medical equipment aligned with the specialization profile.	Alternating current. Oscillation circuits. Quasi-stationary currents. Power dissipation in AC circuits. Electric current in semiconductors. Semiconductor structure. Combinational light scattering. Spontaneous and stimulated emission. Lasers and their operating principles.
4	Biomedical Optics	Obtaining high-precision contrast images of biological tissues for diagnosing diseases. Understanding mechanisms of biological processes through light-tissue interactions.	Determining resistance and power of an incandescent lamp. Measuring lens focal length and optical power. Determining microscope magnification and refractive indices of optically transparent materials. Measuring light wavelength using a diffraction grating.
5	Biomedical Signal Processing	Participating in designing new diagnostic systems, developing specialized transducers, creating software, algorithms, and mathematical methods for automated primary processing of biomedical signals, and developing technical and medical requirements for new and existing devices and systems.	Studying one-way conductivity of semiconductor diodes. Investigating parallel and series conductor connections. Exploring transistor operating principles.

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The figure below illustrates the stages of forming students' professional competencies through interdisciplinary integration of the physics course with biomedical engineering disciplines.

Figure 1: Stages of Forming Students' Professional Competencies through Integration of Physics with Biomedical Engineering Disciplines

Thus, the integration of physics with biomedical engineering disciplines is achieved through physical concepts. Adapting physics to medical and engineering fields lays the foundation for forming the professional competencies required by these specialties.