Semmelweis University, Faculty of Medicine - undivided, one-tier training in general medicine
Name of the host institution (and any contributing institution):
Biofizikai és Sugárbiológiai Intézet

Name of subject in Hungarian: Orvosi biofizika I.
Name of subject in English: Medical Biophysics I
Name of subject in German: Medizinische Biophysik I.

Credit value of the course: 4
Semester: 1st semester
(in which the subject is taught according to the curriculum)

Weekly hours	Lecture	Practice	Seminar
4.0	1.0	3.0	0.0

Semester hours	Lecture	Practice	Seminar
0.0	0.0	0.0	0.0

Type of course:
obligatory

Academic year:
2026/27

Language of instruction (for optional and elective subjects):

Course code:
AOKFIZ1090_1A
(in the case of a new course, to be completed by the Dean's Office, following approval)

Course coordinator name: Dr. Kellermayer Miklós (Intézet igazgató)
Course coordinator location of work, telephone availability: SE Biofizikai és Sugárbiológiai Intézet, 06-1-4591500/60200
Course coordinator position: egyetemi tanár, igazgató
Course coordinator Date and number of habilitation: 2004 PTE ÁOK 7/2004/habil

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Objectives of the course, and its place in the curriculum of the medical training program:

Aim is to give the knowledge and way of thinking necessary for exact and quantitative understanding of working mechanism of biological systems and the human organism.

Format of the course (lectures, group work, practical lessons, etc.):

lectures + practical lessons

Competencies acquired through completion of course:

Understanding the physical background of life processes and the environmental factors influencing the organism (radiations). Doing and evaluation of measurements individually, production of laboratory reports.

Course outcome (names and NEPTUN ID of related subjects):

Prerequisites for course registration and completion: (NEPTUN ID):

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In the case of multi-semester courses, position on the possibility of and conditions for concurrent registration:

We do not give permission for any reasons to take medical biophysics II, only if the exam is passed in medical biophysics I.

The number of students required to start the course (minimum, maximum), method of selecting participants:

Maximum: the number of students in the 1st year.

Detailed course syllabus (if the course can be divided into modules, please indicate): (Theoretical and practical instruction must be broken down into hours (weeks), numbered separately; names of instructors and lecturers must be listed, indicating guest lecturers/instructors. It cannot be attached separately! For guest lecturers, attachment of CV is required in all cases!)

Introduction. Radiations in medicine. Quantities and laws for characterization of common properties of radiations	
Phenomena related to light and geometrical optics. Fermat principle. Light reflection and refraction on planar and curved surfaces, medical optical devices, geometrical optics of the human eye.	
Wave optics as a model. Huygens–Fresnel-principle. the most simple experiment for light interference and its consequences. Resolving power. Light polarization. Color mixing, color vision. Light as electromagnetic wave and as particle. How these two completely different properties can be proven?	
Structure of matter, matter wave, atomic and molecular interactions. Atomic force microscopy.	

Boltzmann distribution, examples. Structural categories of many-particle materials: gas-, liquid-, solid (crystalline)-state of matter, general characteristics. Liquid crytalline (mesomorphous) materials.	
Electronic states in (crystalline) solid materials. Insulators, conductors, semi-conductors. Electric, thermal and optical properties, electro-optical applications.	
Interactions of light with matter. Light scattering, light absorption. Basic principles of absorption spectrometry.	
Laws of thermal radiation and luminescence. Examples for application of them.	
Fundamentals of light amplification. Laser oscillator and its conditions. Properties and medical applications of laser radiation	
Atomic nucleus, radioactivity, nuclear radiations. Interactions of nuclear radiations with matter. Radioactive isotopes, physical basis of radioisotope tracing.	
Dosimetry, radiation protection. Nuclear measurement techniques	
Main problems of nuclear medicine. Radioactive radiations in medical practice. Diagnostic and therapeutic applications of ionizing radiations. Gamma camera.	
Signal processing. Classification of signals. Fourier decomposition. Basic electronic circuits. Semiconductor elements in the circuits. Signal conversion and selection, displays.	

Practices

1	Introduction	
2	Light emission	
3	Resonance	
4	Microscopy I.	
5	Refractometry	
6	Light absorption	
7	Skin impedance	
8	Optics of the eye	
9	Nuclear medicine	
10	Polarimetry	
11	Amplifier	
12	Dosimetry	
13	Gamma absorption	

14. Repetition

Teachers: Dr. Agócs Gergely, Dr. Balog Erika, Dr. Balogh-Molnár Andrea, Dr. Bérces Attila, Dr. Bozó Tamás, Dr. Bőcskei-Antal Barnabás, Dr. Budavári Bálint, Dr. Czigléczki Janka Zsófia, Dr. Csányi

Csilla, Dr. Fehér Bence, Dr. Ferenczy György, Dr. Forgách László, Dr. Galántai Rita, Dr. Gál-Somkuti Judit, Dr. Gresits Iván, Dr. Haluszka Dóra, Dr. Jedlovszky-Hajdú Angéla, Juhász Ákos György, Dr. Juriga Dávid, Halmóczki Sarolta, ,Dr. Herényi Levente, Dr. Kellermayer Miklós Sándor Zoltán, Dr. Kis-Petik Katalin, Dr. Kiss Balázs, Dr. Kiss Bálint, Dr. Kósa Nikolett, Dr. Liliom Károly, Matkovicsné Dr. Varga Andrea, Dr. Mártonfalvi Zsolt, Dr. Molnár Kristóf, Dr. Molnárné Dr. Krisch Enikő, Dr. Orosz Ádám, Dr. Padányi Rita, Pálos veronika Teréz, Dr. Schay Gusztáv, Sipos Evelin, Dr. Simonné Dr. Nagy Krisztina, Dr. Smeller László, Dr. Sziklai Dominik, Dr. Török György, Dr. Veres Dániel Sándor, Dr. Voszka István, Dr. Zolcsák Ádám.

Other courses with overlapping topics (obligatory, optional, or elective courses) in interdisciplinary areas. To minimalize overlaps, topics should be coordinated. NEPTUN ID(s) of courses (to be provided):

Requirements for attendance, options for making up missed sessions, and method of absence justification:

Students may be absent in a maximum of 3 practical sessions during the semester in their own group (according to their Neptun registration). A labreport must be prepared based on the material covered in the practical session, and uploading it to the appropriate platform is a condition for confirming attendance. Missed practical sessions can be made up within the 4–6 week measurement cycle (even in advance) in another group, after prior consultation with the instructors. Completing a practical session in another group does not count as attendance, i.e., it does not reduce the number of absences. Absences from practical sessions do not need to be justified. Any deviation from the above is only possible with the permission of the head of the department or by higher university directive.

Assessment methods during semester (number, topics, and dates of midterms and reports, method of inclusion in the course grade, opportunities for make-up and improvement of marks):
(number, topics, and dates of midterms and reports, method of inclusion in the course grade, opportunities for make-up and improvement of marks)

During the semester, two midterm tests are held: in the week following the 1st and 2nd practical cycles. Each student takes them in their own group (according to Neptun registration) at the scheduled time.

The tests cover both the theoretical background and practical material (representation, evaluation) of the given cycle, in the form of a Moodle test (single-choice, multiple-choice, figures, calculations). The test questions (including partial scores) are made available on the course Moodle page, where students can also practice and learn the correct answers. For calculation tasks, numbers are randomly generated, so the exact numerical result may vary, but correct problem-solving can still be determined.

The midterm tests are considered successful if their average reaches at least 50%.

Missed tests can be made up, and results can be improved in the last week (in the student's own group, during class time), in a similar format, covering the material of both tests. A minimum of 50% must be achieved on this test to pass. If necessary (i.e., if the result is below 50%), further improvement is possible in a similar format during an additional opportunity scheduled in the first week of the exam period.

If the average of the 1st and 2nd midterm tests reaches 80%, the student is exempt from the written part of the exam.

Students who do not need to take a retake or improvement test may take a competitive exam in the last week, through which they can earn a recommended grade of 5 (excellent). This competitive exam includes both similar (but slightly more difficult) closed questions and open-ended questions.

Number and type of individual assignments to be completed, submission deadlines:

A report must be prepared on the material covered in the practical session, and uploading it to the appropriate platform is a condition for confirming attendance. There are no other individual assignments.

Requirements for the successful completion of the course:

A maximum of 3 absences from practical sessions (see point 24) and successful completion of the midterm tests (see point 25).

Type of assessment:
terminal examination

Exam requirements (list of topics, topics of the test exam, and the optional project topics accepted as an exam)

1. **Radiations:** Definition of radiation, possibilities of classification. The concepts and units of radiant power, radiant emittance, and intensity. Dependence of irradiance on the distance from the radiation source. Point, line, and planar radiators. Examples of the application of radiations in diagnostics and therapy.
2. **Light:** General properties of visible light. Physical quantities describing waves and their relationships (speed of light, frequency, wavelength, phase). The electromagnetic spectrum. Examples of the interaction of light with matter, and its significance in medicine.
3. **Geometric optics:** Fundamental principles of geometric optics. The concept of the light ray. Fermat's principle. Laws of refraction and reflection (illustration). Applications of reflection, refraction and dispersion (optical fiber, refractometry).
4. **Optical imaging:** Refraction at a curved surface. Types of lenses and their imaging (with

illustration). Optical power. Lens equation. Properties of the formed image.

5. **Light microscopy:** Image formation in the compound light microscope (figure). Magnification and resolving power. The Abbe principle and Abbe formula. Special light microscopes.
6. **Light as a wave:** Wave motion, types of waves. The Huygens–Fresnel principle. Diffraction of light on an optical grating. The principle of superposition, interference. Spectral decomposition of white light. The limiting effect of diffraction on optical imaging (Airy disk).
7. **Polarization of light:** Linearly and circularly polarized light and their relationship. Optical activity. Polarimetry and Biot's law. The polarizing microscope.
8. **Light as a particle:** The photoelectric effect. The concept of the photon. Practical applications of the photoelectric effect (CCD camera, PMT).
9. **Matter as a wave:** The wave nature of the electron. The de Broglie formula. The Davisson–Germer experiment. Application of matter waves (TEM, cryo-EM).
10. **Classical atomic models:** Early atomic models (Dalton, Thomson). The Rutherford experiment and model. The Franck–Hertz experiment. The Bohr atomic model and its theoretical significance (light emission, spectrum of the H atom).
11. **The quantum mechanical atomic model:** The bound electron as a wave. Heisenberg's uncertainty principle. Quantum numbers. The Pauli principle and Hund's rule. The conceptual structure of the periodic table.
12. **Atomic interactions:** Electronegativity. Potential energy of interactions between atoms as a function of the distance between them. Primary and secondary bonds. Operation and resolution of atomic force microscopy (AFM).
13. **The Boltzmann distribution:** Theoretical foundations of the Boltzmann distribution, its temperature dependence and significance. The Nernst equation. Rate and equilibrium of chemical reactions (Arrhenius plot). The barometric height formula. Electrical conductivity of semiconductors.
14. **Gases:** The ideal gas: kinetic gas theory, origin of gas pressure, Maxwell velocity distribution. The real gas. Equations of state of gases.
15. **Liquids and liquid crystals:** Characteristics of the liquid state. Classification of liquid crystals based on molecular order. Significance and applications of liquid crystals in medicine (thermotropic and lyotropic liquid crystals).
16. **Solids:** Characteristics of the crystalline state. The concept and types of the unit cell. Crystal defects. Energy band structure of electrical conductors and insulators, adaptation of the Pauli principle to crystals. Optical properties of conductors and insulators.
17. **Semiconductors:** Energy band structure of structural semiconductors. Types and applications of doped semiconductors (semiconductor diode, semiconductor dosimeter).
18. **Radiation attenuation:** The law of attenuation of radiation intensity and its mathematical description. Factors influencing the extent of attenuation. Half-value layer, mean penetration depth, attenuation coefficient. Definition of the mass attenuation coefficient and its dependence on photon energy. Examples of medical applications of the attenuation law.
19. **Light absorption:** The general attenuation law. Absorbance and transmittance. Mechanism of light absorption. The Lambert–Beer law. The absorption spectrum (with illustration). Spectrophotometry.
20. **Light scattering:** Definition of light scattering. Rayleigh and Mie scattering. Factors influencing the intensity of scattered light. Applications of light scattering in medicine (dynamic light scattering, turbidimetry, nephelometry).
21. **Thermal radiation:** Definition and energy source of thermal radiation. Kirchhoff's law of radiation. Concept and emission spectrum of the absolute black body. The Stefan–Boltzmann law. Wien's displacement law. Practical applications of thermal radiation (light sources, body

temperature measurement, thermography).

22. **Basics of luminescence:** Definition of luminescence, its types, ant its source of energy. Emission spectra of atoms and molecules. Jablonski diagram, Kasha's rule, Stokes shift. Luminescence lifetime and quantum yield.
23. **Applications of luminescence:** FRAP, FRET, FACS. Fluorescence, confocal and super-resolution microscopies. Flame photometry, germicidal lamp.
24. **Basics of lasers:** Concept of light amplification. Stimulated emission, population inversion, energy pumping, optical resonator.
25. **Applications of lasers:** Properties of laser light. Types of lasers. Medical applications (surgery, dermatology, ophthalmology).
26. **Radioactivity, nuclear radiations:** Composition and stability of the atomic nucleus. Mass defect. The concept of isotopes. Types of radioactive decay, mechanisms of nuclear transformations with examples. Energy spectra of radioactive radiations.
27. **Physical quantities of radioactivity:** Concept and unit of activity. The law of radioactive decay (with graph). Half-life, mean lifetime, decay constant. Medical applications of radioactive isotopes (diagnostics, therapy).
28. **Interaction of nuclear radiations with atomic systems:** Interaction of alpha, beta and gamma radiation with atoms, their maximum ranges in air and in tissue. Neutron and proton radiation, Bragg peak (figure). Dependence of the mass attenuation coefficient on photon energy.
29. **Dosimetry:** Direct and indirect ionization with examples. Direct and indirect radiation effects with examples. Deterministic and stochastic radiation effects with examples. Dose concepts and their units: absorbed dose, exposure, equivalent dose, effective dose, dose rate. Structure, operation, voltage/current characteristic and regions of the ionization chamber (figure).
30. **Radiation protection:** Principles of radiation protection, ALARA principle, some characteristic doses (median lethal and lethal dose; dose of decrease in hematopoiesis, doses of X-ray and CT imaging). Dose rate limit (natural background radiation). Public and occupational dose limits. Structure and operation of the personal dosimeter (thermoluminescent dosimeter).
31. **Isotope diagnostics:** The radioactive tracer method. Criteria of isotope selection. Structure and operation of the technetium generator. Isotope diagnostic procedures: static and dynamic measurements. Typical isotope accumulation curve (figure) and the diagnostic information obtained from it.
32. **Imaging procedures in isotope diagnostics:** Structure and operation of the gamma camera and SPECT. Physical principles of PET imaging.
33. **Radiotherapy:** Physical principles of radiotherapy. Direct and indirect ionization. Types of applied radiation, typical doses, irradiation techniques (teletherapy, brachytherapy, gamma knife).
34. **Medical signal processing:** Concept of signal and information, definition and unit of information content. Types of signals in medicine with examples. Analog and digital signal. Digitization of analog signals, Shannon–Nyquist theorem. Fourier theorem. Fourier transformation in case of periodic and non-periodic signals.
35. **Electrical signal amplification:** Structure of the amplifier. Concepts and mathematical relations of power gain, voltage gain and gain level. Frequency transfer characteristic of the amplifier. Thetransfer band. Positive and negative feedback amplifiers. Structure and operation of low-pass and high-pass filter circuits. Typical voltage amplitude and frequency ranges of medical signals.

The written part of the exam is similar to the midterm tests (see above), but it covers the material of all practical sessions from the entire semester.

Clear, specific minimum requirements for assessment. (The list of mandatory concepts, parameters, diagrams, calculations, and practical skills required to obtain a passing grade, as well as the criteria for the completion and evaluation of project assignments accepted as an exam.) A link published on the department's website referring to the minimum requirements of the course.

The minimum requirement is that the weighted average of the test exam (see point 29) reaches 50%. If it is below 50%, there is an opportunity for an oral explanation of the answers, with assistance, which may modify the original result based on the examiner's judgment. The minimum requirement for the oral part is a passing grade (2) as determined by the examiner. Standardization of examination is supported by the institute's "Teaching the Teachers" project. Students may ask the examiner—during both the study and exam periods—for a subjective estimate of the theoretical weight of concepts and calculations through specific examples.

Method and type of grading (Share of theoretical and practical examinations in the overall evaluation. Inclusion of the results in the end-of-term assessment. Possibilities of and conditions for offered grades.): (Share of theoretical and practical examinations in the overall evaluation, Inclusion of the results in the end-of-term assessment, Possibilities of and conditions for offered grades)

The final grade is the weighted average of the written exam and two oral exam topics, in a 3:2 ratio.

The final grade is the weighted average of the written exam and two oral exam topics, in a 3:2 ratio.

If the average of the 1st and 2nd midterm tests reaches 80% (see point 25), the written exam part is counted as a grade of 5.

Based on the competitive exam (see point 25).

Artificial intelligence systems used in the teaching of the subject and the manner of their application

During teaching and learning, both instructors and students may use artificial intelligence systems with careful consideration and reservations. During exams, only pre-specified AI systems related to the given task may be used. Any non-approved system is not allowed during the exam.

Printed resources:

Type	Mandatory
Author	Damjanovich, Fidy, Szöllősi
Title	Medical biophysics
Publisher	Medicina
Year of publication	2009

Type	Mandatory
Author	Kellermayer et al.
Title	Medical biophysics practices
Publisher	Semmelweis
Year of publication	2015

Signature of habilitated instructor (course coordinator) announcing the course:

Signature of the director of the host institution:

Date of submission: