Medical and Biological Physics
Thematic plan of lectures

TERM 1

Lecture 1. Mechanical oscillations and waves. Acoustics.

The types of oscillations. Simple harmonic motion and damped oscillations. Forced oscillations. Resonance. Mechanical waves: definitions and parameters. Sound, ultrasound and infrasound. Sound intensity and sound level. Decibel. Doppler effect and its application for measuring blood flow velocity. Physics of hearing. Physical and subjective parameters of sound. Phone. Sonic methods in clinics. Phonocardiography. Ultrasound in medical therapy. Ultrasonic cavitation. Physicochemical effects in sonicated solutions and tissues. Ultrasound in medical diagnostics. Acoustic impedance. Infrasound. Infrasound and living organisms.

Lecture 2. Hydro- and hemodynamics. Mechanical properties of biological tissues.

Ideal fluid. Volume flow rate. Equation of continuity for fluid flow. Bernoulli's equation. The examples of medical application of Bernoulli's equation. Real fluid. Viscosity. Newton's equation for viscous fluid. Laminar and turbulent flows. The examples of laminar and turbulent flows in human organism. Poiseuille law. Flow resistance. Physical principles of the measurement of viscosity. Viscometers. Blood viscosity as a biomarker of an pathology. Physical principles of the measurement of blood pressure. Surface tension. Wetting. Capillarity. Gas embolism. Mechanical properties of solids. Stress-strain relationship and moduli. Biomechanics of tissues. Viscoelasticity. Soft and hard tissues in a human organism.

Lecture 3. Bioelectric potentials. Electrography of tissues and organs. Principles of biosignal recording.

Transport of substances across the cell membrane. Passive and active transport. Fick's law of diffusion. Membrane potentials. Resting potential. Nernst and Goldman-Hodgkin-Katz equations. Action potential. Stages. Action potential propagation along myelinated and unmyelinated nerves. Biopotentials. Electrography of organs and tissues. Physical bases of electrocardiography. Dipole, current dipole and electric heart vector. Einthoven theory. Biopotential recording scheme and associated instrumentation. Amplifiers. Gain. Amplitude and frequency responses of an amplifier. Transducers. Temperature transducers. Thermocouple.

Lecture 4. Electrical and magnetic phenomena in living organisms.

Equivalent electrical circuit of living tissue. Impedance of living tissue. The origin of tissue capacitive properties. Primary effects of electrical current on tissues. Application of direct current in medicine: medical galvanization and electrophoresis. Frequency-dependent effects of alternating electric current, alternating electric and magnetic fields on tissues. Application of alternating electric and magnetic fields in medicine. UHF-therapy,

inductothermy, tumor treating fields and surgical diathermy. Electric pulses. Pulsating current and its basic parameters. Biophysical bases of electrostimulation. Irritant action of square pulses. Rheobase and chronaxia. Electrostimulations of the tissue and organs. Types of electrostimulation. Electrostimulators. Generators of pulsating current and pulse shapers (RC-curcuits).

TERM 2

Lecture 5. Geometrical and physical optics. Microscopy.

Basic laws of geometrical optics. Sneel's law of refraction. Absolute and relative refraction indices and their physical sense. Total internal reflection and critical angle. Optical fibers. Endoscopy and its application in medicine. Microscopes. Light and electron microscopes. Scanning probe microscope. Optical compound microscope. Image formation. Limit of resolution and magnification. Fluorescence microscopy. Super-resolution light microscopy. Biophysics of vision. The optical system of the eye. Adaptation and accommodation of the eye. Visual photoreception. Focal power of lens. Defects of vision and their correction. Light as electromagnetic wave. Huygens' principle. Light dispersion. Interference and diffraction of light. Diffraction grating. Condition for the formation of bright fringes. Polarization of light. Polarization by transmission, reflection and refraction. Malus' law. Brewster's law. Double refraction. Polarimetry. Optical activity. Specific rotation.

Lecture 6. Emission and absorption of electromagnetic waves.

The Bohr's model of hydrogen atom. Electron in modern quantum theory. Atomic energy levels and the principal emission series of hydrogen atom. Molecular energy levels. Types of spectra. Spectral apparatuses. Ultraviolet radiation in medicine. Sources of ultraviolet radiation. Infrared radiation in medicine. Light absorption. The law of light absorption. Beer-Lambert law. Light scattering. Tindall's and molecular scattering. Turbidimetry. The general law of decrease in light intensity due to the light absorption and light scattering. Photocolorimetry. Light-transmission factor and absorbance. Measurement of the tissue oxygen saturation level. Photobiological processes. Photosensitive enzymes and biophysics of photoreception.

Lecture 7. Thermal radiation and luminescence.

Thermal radiation. Radiant exitance. Spectral density of radiant exitance and spectral absorption coefficient. Absolute black-body. Laws of the black-body radiation. Thermography. Non-contact determination of body temperature. Luminescence. Stokes shift, quantum and energy yields. Fluoresence and phosporesence. Luminescence in medicine. Chemiluminesence.

Lecture 8. Ionizing radiation. Dosimetry.

X-rays. The sources of X-rays. Electron tube. Braking and characteristic X-rays. The short-wave limit of x-ray spectrum and x-ray radiation intensity. Application of X-rays in medicine. Diagnostic radiology. Therapeutic radiology. Ionizing radiation. Types of ionizing radiation, their penetration and ionizing power. General principles of radiation

protection. Detectors of ionizing radiation. Geiger-Mueller detector. The radioactive decay law. Half-life and activity. Dosimetry. Absorbed dose. Exposure. Dose rate. Biological effects of ionizing radiation. Equivalent Dose. Effective Dose. Collective dose.