

MEDICAL AND BIOLOGICAL PHYSICS

SYLLABUS

INTRODUCTION

Biological and medical physics is a field of science concerned with the study of physical phenomena, physical properties of living organisms, physical aspects of the activity of organs and tissues.

Student should know:

- main laws of Biological and Medical Physics, describing physical processes in human organism
- physical properties of biological organs and tissues

Student should be able to:

- perform statistical calculation on experimental data
- investigate physical properties of substances
- use physical equipment

Student should obtain:

- techniques of measurements different physical characteristics
- practical skills of usage of some medical apparatus

CONTENTS

Introduction to subject

Course Overview. Thematic overview of the 1st and the 2nd terms. Textbooks. Course Requirements and Student Responsibilities. Laboratory safety Requirement. Organization of laboratory and practical classes.

The elements of differential and integral calculus

The derivative and the differential of a function

Function. Independent and dependent variables. The domain and the range. Representation of a function. Function derivative. Geometric sense and physical interpretation of function derivative. Some differentiation rules and formulas. Second-order derivative, higher derivatives. Extremum of function. Differential of a function. Application of differential calculus for approximate calculations. Functions of two or more variables. Differential calculus of functions of many variables: the partial derivatives and the total differential.

The indefinite integral and definite integral

Antiderivative of a function. Indefinite integral. Integral properties. Rules and some formulas of integration. Some techniques of integration. Area of a curvilinear trapezoid. Definite

integral. Newton-Leibniz formula. Definite integral properties. Application of definite integrals for calculation of a work done by variable force.

Differential equations

Definitions and basic concepts of the *differential equation theory*. Classification of differential equations. General and particular solutions. The ordinary first order separable differential equations. Application of differential equations to medical problems. Differential equations drafting.

Theory of probability and mathematical statistics

Basic concepts of Probability theory

Random event. Classical definition of probability. Statistical probability. Random variable. Probability distribution of discrete random variable. Probability density function of continuous random variable. Probability distribution parameters: the expected value, the mode, the median, the variance, the standard deviation. Normal distribution law.

Foundations of mathematical statistics

A subject and problems of mathematical statistics. Sampling method. A statistical population and a sample. Descriptive statistics. Statistical data representation. Tabular arrangement of data: frequency discrete and interval distributions. Graphical formats of data representation: frequency polygons, histograms, pie charts, ogives, boxplots. Point estimates and interval estimates of population parameters. Measures of central tendency: the mean, the median and the mode; measures of variability: the variance, the standard deviation, the minimum and maximum variables, the range, kurtosis and skewness. Confidence interval for estimation of expected value of normally distributed random variable. Calculation of random errors when direct and indirect measurements. Statistical hypothesis testing. Null hypothesis and alternative hypothesis. Type I and type II errors. Significance level. Parametric and non-parametric tests. F-test of the equality of two variances. Two-sample location Student's *t*-test of the equality of two means. Mann-Whitney U test of observations in one sample tend to be larger than observations in the other. The chi-squared test of distribution normality. Correlation. Pearson correlation coefficient. Spearman's rank correlation coefficient. One-way analysis of variance (ANOVA) test.

Separate branches of Mechanics and Biomechanics

Periodic Motion. Mechanical waves. Acoustics

Simple Harmonic Motion. Energy in Simple Harmonic motion. Damped Oscillations. Forced Oscillations. Resonance. Logarithmic damping decrement. Composition of unidirectional oscillations. Composition of perpendicular oscillations. Expansion of compound oscillations in a Fourier series. Mechanical Waves. Transverse and longitudinal waves. Wavelength. Velocity of propagation. Wave function for a sinusoidal plane wave. Wave equation. Energy of wave motion. Intensity. Acoustics. Sound, ultrasound, infrasound. Objective sound wave characteristics. Sound intensity level. Sound Pressure. Threshold of Hearing. Threshold of Pain. Subjective sound perception. Equal Loudness Curves. Ear and hearing. Sound absorption and sound reflection; reverberation. Sources and receivers of ultrasound. Echolocation, therapeutic and surgical application of ultrasound. Doppler effect and its application for non-invasive measurement of blood flow velocity.

Fluids. Physical principles of hemodynamics and rheology

Ideal fluid. Steady-state fluid flow. Laminar and turbulent flow. Reynolds number. The continuity equation. Bernoulli's law. Viscosity. Newton's law of viscosity. Newtonian and non-Newtonian fluids. Poiseuille's law. Hydraulic resistance coefficient. Stokes' law. Viscosity

measurement. Biophysics of blood flow. Determinants of blood viscosity. Physical properties of the vascular system. Fahraeus-Lindqvist effect. Work and power of the heart.

Surface properties of liquids. Surface tension. Surface curvature and pressure. LaPlace's Law. Phenomena of wetting and non-wetting. Capillary attraction. Surface tension measurement. Gas embolism in the vascular system. Surfactant role in respiration.

Mechanical properties of biological tissues

Types of mechanical deformation. Stress-Strain Relationship. Hooke's Law. Young's Modulus. Typical engineering stress-strain plot. Biomechanical function of bones, articular cartilage, joints and muscles, mechanical properties of soft tissues. Active and passive muscle tension. Mechanical modeling of viscoelastic properties of biological materials. Mechanical work of human. Ergometry.

Thermodynamics and Biological thermodynamics

Basic concepts of Thermodynamics. Thermodynamic systems. Heat, internal energy, work done by a gas at constant pressure and at changing gas pressure. Heat Transfer. The first law of thermodynamics and living systems. Heat production and heat loss of human body. Energy expenditure of the organism. Entropy. The second law of thermodynamics. Thermodynamic potentials.

Structural organization and physical properties of cell membrane

Cell membrane. Membrane transport

Cell membrane functions. Cell membrane structure. Physical properties of cell membrane. Membrane transport, two major types. Passive transport, diffusion, facilitated diffusion, osmosis, filtration. Active transport, sodium-potassium pump. Ways of penetration of substances through the cell membrane.

Membrane potentials

Resting membrane potential, theory of Bernstein, Nernst equation. Goldman-Hodgkin-Katz voltage equation. Action potential. Nerve impulse propagation, continuous conduction and saltatory conduction.

Separate branches of Electrodynamics

Electric field characteristics. Electrocardiography

Electric field. Intensity of electric field. Potential of electric field. Dipole, potential of electric field of dipole. Electrograms as the way of study of electric fields of organs and tissues. Electrocardiography, the Einthoven theory. Oscilloscope. Vectorcardiography.

Direct current and alternating current

Galvanic current. Conductivity of electrolytes for DC. Conductivity of biological tissues for DC. Medicinal electrophoresis (Iontophoresis).

Alternating current. Parameters of AC. Resistor in the AC electric circuit. Capacitor in the AC electric circuit. Inductor in the AC electric circuit. Impedance. Power in AC electric circuit. Power factor. Conductivity of biological tissues for AC. The estimation of the viability of biological tissues. Impedance plethysmography (phlebography or reography).

Pulsed electrotherapy methods

Electric Pulse. Pulse parameters. Pulse current and its parameters. Pulse current generators. Differentiator. Integrator. The biological tissue excitation dependence on the pulsed current parameters. Strength-duration curve for an electrically excitable tissue. Lapicque's Equation. Electrical stimulation of biological tissues and organs.

High frequency electrotherapy and electrosurgery methods

LC Oscillator. Generator of high frequency electromagnetic oscillations. Influence of high frequency alternating current on biological tissues. Diathermy methods. Electrosurgery methods. Darsonvalization. Influence of high frequency alternating magnetic field on biological tissues. Influence of high frequency alternating electric field on biological tissues. Influence of high frequency electromagnetic waves on biological tissues.

Components of biomedical measurement systems

Sensors

Structural diagram of medical and biological measuring. Electrodes for reception of biological electric signals. Sensor. Active and passive sensors. Sensors characteristics. Piezoelectric effect. Thermoelectricity. Some types of medical sensors. Temperature sensors. Capacitive and inductive sensors. Resistive sensor. Strain gauge.

Biopotential Amplifiers

Amplifier. Amplitude and frequency characteristics of amplifier.

Optics and Quantum physics

Geometrical optics

Geometrical optics laws. Refracting prism. Refractometry. Total internal reflection. Fiber optics. Lens. Lens aberration. Optical system of eye. Myopia. Hyperopia. Optical microscopy. Magnification and resolution.

Wave optics

Electromagnetic wave properties. Interference of light waves. Huygens–Fresnel principle. Diffraction of light waves. Polarization of light. Malus' law. Polarized microscopy. Polarimetry.

Quantum physics

Energy levels of atoms and molecules. Absorption of light. Beer–Lambert–Bouguer law. Colourimetry. Emission and absorption spectrochemical analysis in medicine. Luminescence. Photoluminescence. Stokes shift.

Thermal radiation, its characteristics. Thermal radiation laws. Thermography.

Bohr model. Spectrum of atomic hydrogen. Electron microscopy. Lasers.

Magnetic field

Magnetic field characteristics. Magnetic force. Spin and orbital magnetic dipole moment of an electron. Magnetic properties of a substance. Electron paramagnetic resonance. Magnetic nuclear resonance. Magnetic nuclear resonance imaging.

Ionizing radiation

Radioactive decay. Bremsstrahlung X-ray. X-radiation. X-ray tube. Medical uses of X-rays.