

# MEDICAL AND BIOLOGICAL PHYSICS

## SYLLABUS

### CONTENTS

#### **Introduction to subject**

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

#### **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 of 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 substances. 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.