SUBJECT:	**BIOPHYSICS AND MEDICAL PHYSICS**				
CREDITS:	Total:	**8.5**	Theory:	**4.5**	Practical: **4**

GENERAL OBJECTIVES

- Apply reasoning methods and the concepts and laws of physics to the study of biomedical processes.
- Understand the relation between molecular structure and energy and the physicochemical properties of solutions.
- Apply thermodynamic concepts and laws in order to understand the energy of biological processes and the human energy balance.
- Apply biophysical concepts in order to understand the transport processes that take place across biological membranes.
- Understand the electrical properties of cells and the nature of the nerve impulse.
- Apply physical concepts and laws in order to explain the vision and hearing processes.
- Understand the laws and general principles of human biomechanics.
- Understand the physical basis for the medical application of ionizing radiations.

SPECIFIC OBJECTIVES

By following the course objectives, students should be able to:

- Describe changes in the electronic structure of atoms and molecules in the absorption or emission of energy.
- Describe the electromagnetic spectrum and explain the effects of different electromagnetic radiations on atoms and molecules.
- Describe the foundations of the most common electroscopic techniques used in medicine.
- Describe molecular structure and polar characteristics.
- Describe the properties of water as a solvent.
- Explain the biological importance of weak interactions.
- Describe interface phenomena and the formation of stable molecular structures.
- Give the thermodynamic characteristics of biological systems and processes.
- Quantify the energy balance of biological processes and the human metabolism using the first law of thermodynamics.
- Apply the second law of thermodynamics to biological systems.
- Relate the state of equilibrium to free energy changes.
- Justify the need for the coupling of exergonic and endergonic processes in biological systems.
- Explain the processes of diffusion across membranes.
- Explain the processes of water transport across membranes.
- Explain the processes of ion transport on an electric potential gradient.
- Describe and explain the solubility of a gas in a liquid and gas transport across a membrane.
- Explain the molecular mechanisms of membrane transport and schematize the different types of transport.
- Interpret the appearance of diffusion potentials and describe the equipment required to record and quantify them.
- Describe the mechanisms behind the generation of membrane potential.
- Describe action potential and relate it to modifications in ionic conductance.
- Explain the mechanisms of nerve impulse conduction along an axon.

- Describe the characteristics of the eye as an optical system and explain the formation of images on the retina.
- Describe the most important optical defects of the eye and indicate the required correction.
- Understand the concept of visual acuity and explain the characteristics of colour vision.
- Explain the mechanism of sound propagation and its dependence on environment.
- Define the intensity of a sound and the decibel scale.
- Define acoustic impedance and explain the reflection and transmission of sound at an interface.
- Explain the mechanism of sound transmission in the ear.
- Demonstrate an understanding of the behaviour of skeletal muscle as a physical entity and how it responds to stimuli.
- Demonstrate an understanding of the physical changes that occur during muscle contraction.
- Demonstrate an understanding of the principles of muscle energetics.
- Describe the effectiveness of muscular force in producing rotation through moments.
- Calculate the value of muscular forces and ligature in articulations.
- Characterize the mechanical properties of tissues.
- Describe the mechanisms of bone fracture.
- Define the magnitudes that describe the circulation of a fluid along a conduit.
- Apply the conservation of energy principle to the circulation of a fluid along a conduit.
- Explain the concept of viscosity of a fluid and interpret the relation between pressure and flow through the concept of *resistance*.
- Evaluate the typical values of hemodynamic resistance of vessels and airway resistance according to their dimensions and the properties of the fluid.
- Interpret the phenomenon of nuclear disintegration and apply the law of radioactive disintegration.
- Describe the interaction of corpuscular and electromagnetic ionizing radiation with matter.
- Describe the working principle of an X-ray tube.
- Describe the physical foundations of image formation techniques through the emission and attenuation of ionizing radiation.
- Explain the principles behind the detection and different units of measurement of ionizing radiation.

PROGRAMME

I. MOLECULAR STRUCTURE AND INTERACTIONS

1. Absorption and emission of energy by atoms and molecules.

1.1. Electronic structure of atoms and molecules.
1.2. Electromagnetic spectrum.
1.3. Interaction of electromagnetic radiation with atoms and molecules.
1.4. Spectroscopic methods with biomedical applications.
1.5. Laser. Thermography. Nuclear magnetic resonance (NMR).

2. Molecular interactions.

2.1. Ionic interaction.
2.2. Electric dipoles.
2.3. Van der Waals interactions.
2.4. Hydrogen bridge. Hydrophobic interactions.
2.5. Energetics of molecular interactions.

3. Solutions and interface phenomena.

3.1. Electrostatic forces and energy in dielectric liquids.
3.2. Solubility of ionic substances in dielectric solvents.
3.3. Water as a solvent medium.
3.4. Interface phenomena. Surface tension.

II. BIOENERGETICS

4. Thermodynamic description of biological systems and processes.

4.1. Microscopic and macroscopic aspects of thermodynamic systems.
4.2. Classification of thermodynamic systems.
4.3. Reversible and irreversible processes.

5. Conservation of energy.

5.1. Molecular interpretation of internal energy.
5.2. First law of thermodynamics.
5.3. Enthalpy. Standard states.
5.4. Energy balance in human metabolism.
5.5. Heat dissipation mechanisms in the body.

6. Entropy and free energy.

6.1. Second law of thermodynamics.
6.2. Stationary non-equilibrium states.
6.3. Free energy. Spontaneity criteria.
6.4. Free energy and work.
6.5. Free energy and equilibrium. Chemical potential.

7. Energetics of metabolic reactions.

7.1. Free energy changes in chemical reactions.
7.2. Relation between the equilibrium constant and free energy.
7.3. Coupling of exergonic and endergonic reactions.

III. MEMBRANE TRANSPORT

8. Diffusion. Osmosis.

8.1. Fick’s Law.
8.2. Permeability.
8.3. Filtration flow.
8.4. Osmosis.
8.5. Filtration flow.

9. Ion flow on an electric potential gradient.

9.1. Electrodiffusion flow.
9.2. Nernst equation.

10. Gas transport across a membrane.

10.1. Partial pressure of a gas in a mixture of gases. Dalton’s Law.
10.2. Partial pressure of water vapour.
10.3. Partial pressure of a gas dissolved in a liquid. Solubility. Henry’s Law.

IV. ELECTRICAL PROPERTIES OF CELL MEMBRANES

11. Membrane potential.

11.1. Diffusion potentials.
11.2. Donnan equilibrium.
11.3. Ionic permeability and membrane potential.

12. Action and conduction potential of electrical impulses.

12.1. Current-voltage relationship.
12.2. Passive propagation of potential changes.
12.3. Action potential.
12.4. Action potential conduction.

V. SENSORY BIOPHYSICS

13. Biophysics of vision.

13.1. Optical system of the eye.
13.2. Ametropia and correction.
13.3. Visual acuity and colour vision.

14. Biophysics of hearing.

14.1. The nature of sound.
14.2. Intensity. Decibel scale.
14.3. Sound propagation. Acoustic impedance.
14.4. Transmission of sound in the ear.

VI. BIOMECHANICS

15. Biophysics of muscle contraction.

15.1. Mechanics of contraction in skeletal muscle.
15.2. Muscle response to stimuli.
15.3. Types of contraction.
15.4. Force-length relationship.
15.5. Muscle energetics.

16. Musculoskeletal mechanics.

16.1. Reduction of a system of forces on a rigid solid.
16.2. Equilibrium of forces acting on joints. Ligature forces.
16.3. Calculation of forces acting on joints.
16.4. Biomechanics of human equilibrium.

17. Elasticity.

17.1. Force-deformation relationship.
17.2. Linear elasticity. Young's model.
17.3. Nonlinear elasticity. Point of fracture.

18. Mechanical properties of bones.

18.1. Bone resistance to traction and compression.
18.2. Bone resistance to flexion.
18.3. Bone resistance to torsion.

19. Mechanical properties of soft tissue.

19.1 Force-deformation relationship in soft tissue.
19.2. Hysteresis. Energy dissipation.
19.3. Laplace's Law.

20. Fluid dynamics.

20.1. Conservation of energy. Bernoulli's Equation.
20.2. Viscosity. Poiseuille's Law.
20.3. Hemodynamic resistance and airway resistance.

VII. RADIOPHYSICS

21. Radioactivity.

21.1. Structure of the nucleus.
21.2. Nuclear stability. Radioactive nuclei.
21.3. Law of radioactive disintegration.
21.4. Medical applications of radioactive isotopes.

22. Interaction of corpuscular radiation with matter.

22.1. Classification of corpuscular ionizing radiations.
22.2. Collision and braking processes.
22.3. Energy transfer in irradiated environments.

23. Obtaining and modulating X-rays.

23.1. Working principle of an X-ray tube.
23.2. Spectrum of an X-ray tube.
23.3. Modulation of X-ray beams.

24. Interaction of photons with matter.

24.1. Photoelectric, Compton and materialization effects.
24.2. Energy transfer in irradiated environments.
24.3. Photon attenuation. Radiographic contrast.

25. Molecular and cellular effects of ionizing radiation.

25.1. Radiolysis of water.
25.2. Molecular effects of ionizing radiations.
25.3. Cellular effects of ionizing radiations.

26. Detecting and measuring ionizing radiation.

26.1. Principles of ionizing radiation detection.
26.2. Units of measurement for radiation.
26.3. Dosimeters.

LEARNING RESOURCES AND TEACHING METHODOLOGIES

Theory credits

Teaching of theoretical elements (4.5) will be classroom-based.

Practical credits

Teaching of practical elements (4.0) will be divided between:

- seminars (2.2 credits)
- practical laboratory sessions (1.8 credits).

LEARNING REQUIREMENTS

Teaching is provided on the assumption that students possess knowledge of Physics, Mathematics, Chemistry and Biology equivalent to higher secondary education level.