MEDICAL UNIVERSITY OF ŁÓDŹ

PREMEDICAL PREPARATORY COURSE (SYLLABUS)

1. Name of the department providing the course: Zakład Chemii i Biochemii Klinicznej

2. Course title: Physics

3. Course language: English

4. Type of course unit: compulsory

5. Course aims: As a result of the implementation of the curriculum course the students gain knowledge about the physical processes taking place in the environment around us and are able to apply the information obtained in further stages of learning, during classes in chemistry, biology, genetics, and clinical physiology. The experience gained in laboratory work also gives the students the skills needed in the course of further studies, medical diagnostics, and in subsequent scientific and research work.

7. Names of course unit's faculty: dr hab. Robert Stawski, dr. Igor Sokołowski

8. Prerequisites: none

9. Learning activities and teaching methods: lectures (both in form of shared files and tests on Pearson platform, seminars and laboratories.

10. Course unit content: Lectures

(Integrated Curriculum: Combining standard Giancoli physics foundations with clinical medical applications)

1. **Measurement Uncertainty, Kinematics & 1D Movement in Medicine**
   - *Pearson Foundations:* Types of errors, error calculations, reporting the measurements, Units, Instantaneous velocity, Displacement vector.
   - *Clinical Integration:* Accuracy vs. precision in medical diagnostics (lab reference values, blood pressure categories); Medical units and dosage errors (e.g., mg/kg/day); Physics in diagnostics: MRI (Nuclear Magnetic Resonance) and ECG (bioelectricity); Limits of human tolerance to longitudinal overloads.
2. **2D Motion & Newton's Laws in Biomechanics**
   - *Pearson Foundations:* Instantaneous & average acceleration, Uniformly accelerated motion, 2D projectile motion, Newton's laws of motion - introduction, Assumptions for 2D motion.
   - *Clinical Integration:* Applying Newton's Laws to biological systems (e.g., sudden ambulance stops, whiplash); Calculating injection force and trauma impacts; Biomechanics of gait and surgical tool manipulation; Hemodynamics (blood pressure as an action-reaction pair).
3. **Friction, Simple Machines & Circular Motion in Clinical Practice**
   - *Pearson Foundations:* Friction, normal force, Apparent weight, Weightlessness, Free body diagram, Simple machines, Newton's Law of Universal Gravity, Circular motion.

- *Clinical Integration:* Static and kinetic friction in patient transfer and joint cartilage ($\mu \approx 0.001$-0.01); Orthostatic hypotension diagnosis; Physiological impacts of microgravity (cardiovascular deconditioning, muscle atrophy); Mechanical advantage in medical instruments (extraction forceps, scalpels, bone chisels); Vestibular system as a natural gyroscope (vertigo); Centrifugation in medical labs (RCF).

4. **2D Gravity and Circular Motion**
   - *Pearson Foundations:* Newton's Law of Universal Gravity, Keppler laws, Circular motion (accelerated and constant).
   - *Clinical Integration:* Artificial gravity calculations for space missions; Centripetal acceleration in centrifuges for separating blood components; Coriolis effect in blood flow patterns; Kepler's laws for medical satellite orbital periods.
5. **Work, Energy, Power & Linear Momentum; Impulse**
   - *Pearson Foundations:* Work-units and calculation, Work-energy theorem, Gravitational potential energy, Power - units and theorem, Conservation of energy, Linear momentum.
   - *Clinical Integration:* Energy scale in the human body (heart beat ~0.5 J, ATP hydrolysis); Power output of the human body (BMR ~80 W, athlete ~2000 W); Momentum in biomechanics (why airbags, padding, and bent knees work by increasing time to reduce average force).
6. **Collisions & Rotational Motion**
   - *Pearson Foundations:* Collisions types, Two-dimensional collisions, Center of mass, Rotational motion, Rigid object assumptions, Angular displacement.
   - *Clinical Integration:* Center of Mass in the human body (overall CoM vs individual segments, walking vs standing with a walker); Joint motion and fractures (angular displacement in flex/extension).
7. **Rotational Motion, Mechanical Waves & Acoustics (Hearing)**
   - *Pearson Foundations:* Rotational kinematics, Centripetal acceleration, Resultant acceleration, Rotational kinetic energy, Mechanical waves - introduction (sound), Interference, Principle of superposition.
   - *Clinical Integration:* Physics in medical imaging (MRI, Ultrasound). Biophysics of Hearing: Mechanical nature of sound waves (intensity/loudness, frequency/pitch); Impedance matching in the middle ear; Frequency analysis by the basilar membrane (tonotopic organization) in the Organ of Corti; Vestibular system (equilibrium and acceleration detection); Audiometric hearing tests and types of deafness.
8. **Temperature and Kinetic Theory**
   - *Pearson Foundations:* Atomic theory, Brownian motion, Temperature scales, Zeroth law of thermodynamics, Thermal expansion, Gases introduction and pressure.
   - *Clinical Integration:* Clinical temperature ranges (Hypothermia to Hyperpyrexia in °C and °F); Arrhenius principle (optimal enzyme efficiency at 37°C, hypothermia protecting tissues during surgery); Thermoregulation by hypothalamus; Gas laws applied to respiratory physiology and ventilators.

9. **Kinetic Theory and Calorimetry**

   - *Pearson Foundations:* Heat as energy transfer, Kinetic theory, Equipartition of energy, Molar specific heat, Phase Change.
   - *Clinical Integration:* The body as a thermal system (metabolism as the thermal engine); Specific heat of water (body is ~60% water, enabling stable temperature); Phase changes (sweating as latent heat, fever vs hyperthermia); Indirect calorimetry (O_2 consumption/CO_2 production); Thermography in diagnostics.

10. **The Laws of Thermodynamics**

   - *Pearson Foundations:* Thermodynamics - basic terms, The zeroth law of thermodynamics, The first law of thermodynamics, Processes and the first law, Work and volume changes, The second law of thermodynamics, Heat engines.
   - *Clinical Integration:* Zeroth Law and reliable body temperature measurement; First Law applied to human energy budget (stable patient $\Delta U \approx 0$) and pressure-volume work of the beating heart; Second Law (entropy) as a measure of system health (ischemia/necrosis = increased entropy); The human body as a low-efficiency (10-20%) heat engine where waste heat is essential for thermoregulation.

11. **Carnot Engine & Electric Field Introduction**

   - *Pearson Foundations:* Carnot engine - principle of working, Carnot cycle, Entropy, Electric charge in the atom, Electric charge and its conservation, Static electricity, Coulomb's law.
   - *Clinical Integration:* Human body vs. Carnot Engine (metabolism and ATP); Static electricity warnings in medical devices (ECG/EEG grounding); Coulomb's Law in biology (ionic bonds, membrane potential, action potential); Ventricular Fibrillation as maximal electrical entropy, treated by defibrillation (electrostatic reset).

12. **Electric Potential**

   - *Pearson Foundations:* Electric potential energy, Electric potential difference, Relation between electric potential and electric field.
   - *Clinical Integration:* Resting membrane potential (~-70 mV) and action potentials; Diagnostic tools measuring physiological potential differences (ECG/EKG, EEG, EMG); Therapeutic interventions using potentials (Pacemakers, Deep Brain Stimulation); Arrhythmias as electrical disorders.

13. **Capacitance**

   - *Pearson Foundations:* Equipotential lines and surfaces, Electric potential vs distance from point charge, Electric Dipole Potential, Capacitance and units, Capacitors in Parallel/Series.
   - *Clinical Integration:* The cell membrane modeled as a biological capacitor (lipid bilayer as the dielectric insulator, intra/extracellular fluids as conductive plates, ion channels as resistors/voltage sources); Electric dipoles in biological molecules.

14. **Electric Current part 1**

- *Pearson Foundations:* Dielectric in capacitor - mechanism, Energy Storage in Capacitors, Ohm's law, Resistivity, Resistance and resistivity, Parallel and series circuits - resistors.
- *Clinical Integration:* Biological dielectrics; Tissue resistivity (blood vs fat vs bone); Body Composition Analysis (BIA) measuring fat vs fat-free mass using electrical resistance; Demyelinating diseases (e.g., Multiple Sclerosis) altering nerve resistance and capacitance.

15. **Electric Current part 2**
    - *Pearson Foundations:* Kirchhoff's Laws - topology, Kirchhoff's Current Law, Kirchhoff's Voltage Law, Alternating Current - introduction, Electric power, Transformers.
    - *Clinical Integration:* Circuit topology in hemodynamics (nodes = vessel junctions, loops = systemic/pulmonary circulation, Kirchhoff's Current Law = blood in equals blood out); Cardiac conduction loop (SA node to Purkinje fibers); AC-like biological signals vs. DC shocks in defibrillators; Medical use of electric power (electrocautery/diathermy vs. electrical burns); Isolation transformers in operating rooms for patient safety; High-voltage transformers in X-ray and CT scanners.
16. **Magnetic Field**
    - *Pearson Foundations:* Magnetism, Magnetic field, Magnetic field characteristics, Right hand rule, Vector product, Lorentz force, Electrodynamic force.
    - *Clinical Integration:* Magnetic fields in diagnostic imaging (MRI and the B_0 field); Protons as moving charges affected by the Lorentz force; Pacemaker shielding requirements from external magnetic fields.
17. **Electromagnetic Induction Faraday's Induction Law**
    - *Pearson Foundations:* Electromagnetic field - induced fields, Magnetic flux, Faraday's law, Lenz's rule.
    - *Clinical Integration:* Faraday induction as the basis for detecting MRI signals (changing magnetization inducing current in receiver coils); Transcranial Magnetic Stimulation (TMS) using induced currents for neurological treatment; Magnetotherapy for bone healing.
18. **Geometric Optics Introduction**
    - *Pearson Foundations:* Principles - optics, Geometrical optics - model of rays assumptions, Fermat Rule, Reflection, Total Internal Reflection, Refractive Offset, Spherical Lenses.
    - *Clinical Integration:* Fermat's Principle in understanding light path through ocular structures; The eye as a refractive system (total refractive power ~59 diopters); Refractive errors (Emmetropia, Hyperopia, Myopia, Astigmatism, Presbyopia) and their correction using spherical and cylindrical lenses.
19. **Optics part 2**
    - *Pearson Foundations:* Optical Instruments, Combinations of Lenses, Cameras, Flat Mirror Image, Spherical Mirrors, Converging Lenses, Lens Maker's Equation.

- *Clinical Integration:* Diagnostic optical instruments (ophthalmoscope, tonometer principles); Stereoscopic vision and binocular disparity for depth perception; Retinal imaging diagnostics (detecting cotton wool spots, optic disk edema, macular degeneration); Neurological aspects of vision (pupil light reflex, optical illusions).

20. **Radioactivity and Nuclear Physics in Medicine**

- *Pearson Foundations:* Basic nuclear structure (protons, neutrons, isotopes); Types of radiation (Alpha, Beta, Gamma); Half-life and radioactive decay.
- *Clinical Integration:* Diagnostic vs. therapeutic isotopes (e.g., 99mTc, 18F for PET, 131I for thyroid therapy, 223Ra for bone metastases); Biological effects of radiation (DNA damage vs. cell death); Principles of radiotherapy and stereotactic radiosurgery (Gamma Knife); Radiation safety and relative dose context (dental X-ray vs. CT vs. background radiation).

Seminars and Laboratories:

Seminars serve as conection between translating lecture concepts into preclinical problem-solving. Through directed case studies and biophysical modeling. Students will analyze the physical mechanisms underlying pathological states and standard medical instrumentation.

Key educational components include:

- Clinical Case Studies and physical aspects of diagnostics: Applying physical laws to interpret clinical manifestations and diagnostic findings , basics of diagnostic devices and medical diagnostics (Spirometry, ECG EEG, radiology).
- Optics and Visual Biophysics: Studing of the physics of image formation, refraction, visual acuity, accommodation mechanisms, and common optical aberrations, along with corrective modalities and diagnostics.
- Acoustics and Auditory Biophysics: Will be focused on physical properties of sound waves, acoustic impedance, and the psychoacoustic scales of frequency and intensity. Students analyze the biomechanical mechanisms of hearing, specifically focusing on middle-ear impedance matching and tonotopic frequency decoding within the cochlea. Clinical problem-solving centers on interpreting pure-tone audiograms and differentiating conductive from sensorineural hearing loss using acoustic diagnostics and tuning fork examinations.

Laboratories: Students prepare physical experiments and carry out precise measurements and will be introducted to selected medical equpments. A central goal is translating biophysical principles into clinical understanding through c during data acquisition, directly mimicking clinical diagnostic environments.

Key hands-on diagnostic modules encompass:

- Sensory Biophysics & Neuromuscular Assessment: Quantitative sensory testing (QST) evaluating cutaneous pain thresholds and pallesthesia (vibration perception threshold).
- Diagnostics of Acoustic and Audiology: Principles of bone vs. air conduction via tuning fork examinations (Rinne, Weber) and threshold screening audiometry.

- Body Composition & Bioimpedance: Evaluation of cellular hydration, tissue resistance, and reactance using bioelectrical impedance analysis (BIA).
- Visual Biophysics and Diagnostics: Measurment of visual acuity (Snellen chart), screening for corneal astigmatism (astigmatic dial test), evaluation of direct and consensual pupillary light reflexes, and practical demonstration of photoreceptor adaptation via positive and negative visual afterimages.

Required and recommended learning resources (readings):

- **Required:** "Physics 7th Ed." Giancoli
- **Required:** Supplemental clinical physics lecture materials and case studies (dr hab. Robert Stawski, dr. Igor Sokołowski)
- **Recommended:** Pearson remote learning platform resources