



## **COURSE DESCRIPTION AND STUDY REGULATIONS**

Course: Biophysics

Study Programme: Medicine

Year of the Course: 1

Semester: Winter

Course type: Compulsory

ECTS credits: 7

Lecturer(s): Jure Derganc

Valid for academic year: 2020/2021

Participating Organisational Units: Institute of Biophysics

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### **1. Course objectives**

Students acquire the principles of quantitative problem solving in medicine. They learn the basic physical laws and their application to human physiology, diagnostics and medical treatment. They learn about the measurements of the physical parameters in simple systems.

### **2. Course description**

The course is taught in the first semester, in the form of lectures (4 hours per week for 15 weeks), practical lessons/seminars (1 hour per week for 15 weeks) and laboratory lessons (2 hours per week for 15 weeks). The schedule will be amended according to the situation with COVID-19.

The aim of the practical lessons is to discuss and consolidate the topics that have been addressed in lectures, and apply the acquired knowledge to specific sets of problems. In laboratory lessons, the students perform a set of laboratory assignments and prepare lab reports. The assignment schedule for each student is announced at the beginning of the semester. The schedule of laboratory assignments is different for each student and does not follow the course of the lectures. Participation in practical and laboratory lessons is mandatory. In the event of a justified absence, the laboratory assignments can be re-scheduled by the assistant.

The on-going assessment of knowledge consists of regular evaluation at practical and laboratory lessons, and two preliminary exams (the first in the mid-semester and the second at its end). The final exam consists of a written and oral exam in the examination periods.

### **3. Description of assessment of knowledge and skills during the course**

The on-going assessment of knowledge and skills during the course consists of evaluation at practical and laboratory lessons, and two preliminary exams (the first in mid-semester and the second at its end). The evaluation at practical and laboratory lessons is based on the student's knowledge demonstrated at the lessons, skills demonstrated at laboratory exercises, the quality of lab reports and the student's overall engagement in the lesson. The impact of the on-going assessments on the final exam is described in detail in Chapter 5. Final examination.

The application for the on-going assessment of knowledge via the Student Information System of FM is not required.

### **4. Eligibility requirements for the examination (course exam)**

A required condition for entering the final exam is a positive grade in assessment of practical and laboratory lessons (at least 11 points). Lab reports must be submitted and assessed before the beginning of the exam week.

### **5. Final examination (Course exam): description of examination procedure**

The final examination comprises a written and an oral part. The examination application must be submitted in a timely manner via the Student Information System of FM (<https://vismf.uni-lj.si/>).

The final grade for the course is determined at the oral exam. The entrance grade for the oral exam is determined with respect to the total number of points scored in preliminary exams (the first preliminary exam counts max 15 points, and the second 20 points), the evaluation of practical and laboratory lessons (max 15 points) and the written exam (max 50 points). The grade scale is described in the Regulations for Assessment of Knowledge and Skills for the Uniform Master's Study Programmes of Medicine and Dental Medicine. The student will only be admitted to the oral exam if he / she has a positive grade in the written exam (at least 25.2 points), or at least 20 point average of two consecutive written exams. In the latter case, the student has to pass also an oral defence of the written exam. The final grade is based on the performance at the oral exam and may be different from the entrance grade. Students with more than 70 points (grade 8 or higher) can be exempted from the oral exam. In the case of justified absence from the

preliminary exams, the missing grades can be acquired by answering additional questions at the oral exam. In the event of repeated examinations, the written part of the examination is re-examined. Students who have failed the exam twice are admitted to the oral examination even with less than 25.2 points on the written exam.

The topics of the written exam comprise lecture topics, problem solving related to practical lessons and exercises related to laboratory lessons. The topics of the first preliminary exams comprise lecture topics and problem solving. The second preliminary exam focuses predominantly to topics covered in laboratory lessons. The correct answers in written exams are scored by 1 point, and wrong answers can result in a deduction of -0.2 points. At the oral exam, the knowledge gained in lectures, practical and laboratory exercises is evaluated. Students who did not show satisfactory knowledge in problem solving or laboratory-related exercises at the written examination receive additional questions from the relevant content at the oral examination.

The exam schedule is determined at the Council of the Year, at the beginning of the first semester.

## 6. Additional provisions related to student assessment

Permitted accessories for written exams are: a pen, a standard (non-graphic) scientific calculator, a ruler/protractor.

## 7. Fundamental study material and Supplement reading

Fundamental literature (the literature is freely accessible on the homepage of the Institute of Biophysics):

- Skripta Biofizika za medicino (lecture notes).
- B. Božič, J. Derganc, G. Gomišček, V. Kralj-Iglič, J. Majhenc., P. Peterlin, S. Svetina, B. Žekš: Praktikum iz biofizike (instructions for the laboratory classes).
- Več avtorjev: Zbirka računskih nalog za biofiziko (lecture notes).

Additional literature

- izbrana poglavja iz R. Kladnik: Visokošolska fizika, I, II in III del, Državna založba Slovenije, 1985.
- F. Sevšek: Biomehanika, Visoka šola za zdravstvo, 2004.
- S. Amador Kane. Introduction to Physics in Modern Medicine. CRC Press, 2009.
- PP Urone et al.: College Physics, <https://openstax.org/details/college-physics>
- C.R. Nave et al.: HyperPhysics, <http://hyperphysics.phy-astr.gsu.edu/>
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## 8. Exam topics, clinical presentations and skills

### Quantitative description of natural phenomena

- 1) physical quantities, units
- 2) basic mathematical functions, exponential changes (first-order reactions)
- 3) graphs, linearization, log-log graphs
- 4) non-linear dependence between quantities; Drain, integral

### Mechanics

- 5) description of motion (position, velocity, acceleration and relations among them)
- 6) types of motion (uniform, accelerated, mixed, three-dimensional)
- 7) rotation (description, acceleration, analogy between linear and circular motion)
- 8) differences between point and rigid bodies, degrees of freedom

- 9) 2. Newton's law of motion (force, torque, mass, moment of inertia)
- 10) conservation of momentum and angular momentum
- 11) work, kinetic, rotational and potential energy, conservative and dissipative forces
- 12) conservation of mechanical energy
- 13) differences between solid substances, liquids, fluids and gases
- 14) fluids at rest
  - i) pressure, Archimedes' principle
  - ii) compressibility
  - iii) surface tension
    - (a) Laplace's law
    - (b) wetting
    - (c) capillary action
    - (d) surfactants
- 15) elastic properties of matter
  - i) tensile, shear, torsional load and corresponding Hook laws
  - ii) strain-stress diagram for a simple elastic substance
- 16) fluids in motion
  - i) description of flow, volume flow, flow rate vs. velocity, laminar/turbulent flow (Reynolds number)
  - ii) Bernoulli's equation
  - iii) square law of resistance
  - iv) viscosity
  - v) linear law of resistance: Stokes' law
  - vi) velocity profile in the vessel, connection between the maximum and average velocity
  - vii) Hagen-Poiseuille's law
  - viii) Ostwald viscosimeter
- 17) sedimentation
- 18) mechanical equilibrium, centre of gravity (mass centre)
- 19) oscillations
  - i) description of oscillation
  - ii) examples of pendulums
  - iii) resonant frequency
  - iv) damped oscillation
  - v) forced oscillation
  - vi) resonance

## Thermodynamics

- 20) basic characteristics of thermodynamic systems
- 21) thermal motion, diffusion
- 22) internal energy
- 23) the connection between the microscopic and the macroscopic picture of the ideal gas (gas equation, internal energy of ideal gas, partial pressure in gas)
- 24) temperature, temperature measurement and temperature scales
- 25) work, heat
- 26) 1st law of thermodynamics
- 27) calorimetry, specific heat, thermal capacity, heat of fusion and vaporization
- 28) specific heat of ideal gases
- 29) enthalpy, Hess' law
- 30) isothermal and adiabatic processes
- 31) entropy, microscopic image of entropy
- 32) 2. The law of thermodynamics
- 33) calculation of the entropy change
- 34) thermodynamic potential at a given p and T: free enthalpy (Gibbs energy)
- 35) multiphase systems, chemical potential, balance, equilibrium distribution of substances between phases (Boltzman factor)

- 36) chemical potential of ideal gas
- 37) dissolution of gases, chemical potential of the solute
- 38) osmotic pressure, chemical potential of the solvent
- 39) phase diagram of water
- 40) saturated vapour pressure, humidity
- 41) transport phenomena (Ohm's law, current, flux, stationary state, resistor combinations)
  - i) heat transfer
  - ii) diffusion
  - iii) non-stationary state and approach to equilibrium
  - iv) transport across the membrane (passive and active transport)
    - (a) membrane permeability
    - (b) facilitated transport

### **Electricity and magnetism**

- 42) electric charge, charge in biological systems, pH
- 43) electric field and the electric force
- 44) electric potential, equipotential surfaces, voltage and energy of the electric field
- 45) electric dipole
- 46) torque on the electric dipole in the electric field
- 47) electric field in matter
  - i) conductors (metal, ionic solution)
  - ii) isolators (polarizability, dielectric materials, polarization)
- 48) the field near an infinite charged plate
  - i) in an empty space
  - ii) in a dielectric material
  - iii) in an ionic solution (Debye's length)
- 49) capacitor
- 50) electric current
  - i) effects of an electric current
  - ii) mobility, specific conductivity, specific resistance, resistance, basic knowledge of electrophoresis
  - iii) current dipole
  - iv) Ohm's law, resistor combinations, electric power
- 51) origins of electric potential
  - i) contact potential
  - ii) electrode potential
  - iii) the diffusion potential
  - iv) membrane potential (Nernst's and Goldman's equation)
  - v) membrane potential in the red blood cell (Donnan equilibrium)
- 52) ECG and basic knowledge of electroencephalography (EEG) and electromyography (EMG)
- 53) electric conduction in the nerve fibres
- 54) magnetic field
  - i) magnetic field
  - ii) Amper's law and basic knowledge of magnetoencephalography (MEG)
  - iii) magnetic field of the current loop, the coils, the energy of the magnetic field
  - iv) force between conductors
  - v) force on a moving charge, basic knowledge of mass spectroscopy
  - vi) Hall's effect
  - vii) law of induction, basic knowledge of transcranial magnetic stimulation (TMS)
  - viii) magnetic dipole and the torque in magnetic field
  - ix) magnetic field in matter, a magnetization
- 55) alternating current
  - i) effective voltage
  - ii) capacitors and coils in an alternating-current
- 56) discharging and charging of capacitors

## Fundamentals of molecular biophysics

- 57) hydrogen atom, the energy states of the atom, the shell, and the subshell, quantum numbers
- 58) atoms with several electrons
- 59) combining atoms into molecules, dissociation energy
- 60) strong interatomic bonds
  - i) ionic bond, metal bond
  - ii) covalent bond
- 61) spatial and electronic structure of simple molecules (H<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>O, NH<sub>3</sub>, CH<sub>4</sub>)
- 62) electrical properties of substances: conductors, insulators, semiconductors
- 63) excited states of molecules
- 64) weak interatomic bonds
  - i) polar interactions
  - ii) hydrogen bond
  - iii) Van der Waals interaction
  - iv) hydrophobic interaction
- 65) properties of the water molecule
- 66) protein structure, peptide bond
- 67) DNA structure
- 68) lipid membrane structure

## Waves

- 69) general characteristics of waves
  - i) description (frequency, wavelength, velocity, phase)
  - ii) energy flux, energy density
    - (a) divergence / convergence of rays
    - (b) law of absorption
  - iii) reflection and refraction law, total reflection, basic knowledge of endoscopy
  - iv) interference
  - v) diffraction
  - vi) diffraction grid
  - vii) scattering
  - viii) standing wave
  - ix) spectrum
- 70) sound and ultrasound
  - i) basic characteristics
  - ii) sound intensity and decibels
  - iii) Doppler effect
  - iv) use of ultrasound in medicine
  - v) hearing and speech
- 71) electromagnetic waves
  - i) basic characteristics, the EM spectrum
  - ii) energy of EM waves and quantum picture
  - iii) fluorescence
  - iv) thermal radiation
  - v) light spectroscopy, photometer, basic knowledge of pulse oximeter
  - vi) laser, medical use of laser
- 72) optics
  - i) lens, lens power, lens equation, image formation, two-lens systems
  - ii) magnification, simple magnifier
  - iii) microscope, magnification, resolution
  - iv) eye, accommodation, near-sightedness, far-sightedness
- 73) X-rays
  - i) production of X-rays
  - ii) spectrum

- iii) interaction with matter
  - iv) use in medicine
  - v) basic knowledge of computer tomography (CT)
- 74) magnetic resonance
- i) excitation and relaxation, relaxation times
  - ii) magnetic field gradient and a spatial picture

### **Atomic nucleus**

- 75) nucleus composition, size
- 76) binding energy, mass defect
- 77) radioactivity, nuclear decay / reactions
- i) alpha
  - ii) beta plus, beta minus, electron capture
  - iii) gamma
  - iv) nuclear fission
  - v) activity, half-life, decay constant
- 78) interaction of radioactive rays with matter
- 79) Geiger-Mueller tube
- 80) effects of ionizing radiation on tissue
- 81) doses
- 82) an overview of ionizing radiation
- 83) basic knowledge of the use of ionizing radiation in medicine: therapeutic irradiation (accelerators, brachytherapy, radioactive sources), diagnostics (PET, scintigraphy)

### **Miscellaneous**

- 84) basics of measurement, analysis of measurements, evaluation of measurement errors
- 85) tracer methods, volume determination, determination of the velocity constant during the exchange of matter between compartments
- 86) two-exponential kinetics (the content of the Lab Assignment #2)

## **9. Other**

Additional information on the study regime at the Faculty of Medicine is available in the Regulations for Assessment of Knowledge and Skills for the Uniform Master's Study Programmes of Medicine and Dental Medicine.