Medical biophysics final exam questions 2016/17 (EM)

(I. semester)

1. Radiations.
   Basic concepts: Radiation source, radiation, irradiated target.
   Phenomena: Decrease of radiation „strength" for various reasons.
   Physical quantities: Radiant power (P), radiant emittance, irradiance (M, E_{in}), radiant flux (I_E), radiant flux density or intensity (J_E), solid angle (Ω).
   Laws, relations: Dependence of irradiance on the symmetry of radiation source, on the distance from it and on the angles of observation. The decrease of intensity passing through medium.
   Applications: X-ray image. Designing irradiation for therapeutic radiation.

2. Fundamentals of geometric optics.
   Basic concepts: Geometric optics as a model. Light ray, normal of incidence (optical axis), Fermat's principle.
   Phenomena: Propagation of light in straight line, reflection, refraction. Total reflection.
   Physical quantities: Angles (α, β), absolute and relative indeces of refraction (n), light velocity in a medium (c).
   Laws, relations: Law of propagation, reflection and refraction of light.
   Applications: Refractometry. Endoscopy.

3. Image formation in simple optical systems based on geometric optics.
   Basic concepts: Light ray, normal of incidence, optical lens, image, Fermat's principle, optical path length.
   Phenomena: Image formation.
   Physical quantities: Angles (α, β), absolute and relative index of refraction (n), light velocity in a medium (c), object distance (o), image distance (i), focal length (f), magnification (M).
   Laws, relations: Snell's law. Image formation by a simple curved surface. Image formation through multiple curved surfaces. Lens equation.
   Applications: Optics of the human eye. Visual acuity, geometric resolution, correction of refractile disorders, accommodation. Image formation of lenses, simple magnifier, depth of field. Image formation in the light microscope.

4. Fundamentals of wave optics.
   Basic concepts: Huygens-Fresnel principle.
   Phenomena: Light interference, diffraction, polarization, birefringence.
   Physical quantities: Amplitude (A), frequency (f), period time (T), wavelength (λ), light velocity (c), phase (φ), phase difference ($\Delta\varphi$).
   Laws, relations: Relations between the characteristic physical quantities. Transformation of path and time differences into phase differences. The meaning of color (f, λ_{vacuum})
   Applications: Resolving power of the light microscope determined by the diffraction limit, Abbe's principle.

5. Simple phenomena, that can be understood based on the wave optics.
   Basic concepts: Wave optics as model. Oscillations, coherent and non-coherent waves. Huygens-Fresnel principle. The observed pattern
   Phenomena: Young's experiment with double slit. Diffraction on optical grating.
   Physical quantities: Amplitude (A), frequency (f), period time (T), wavelength (λ), light velocity (c), phase (φ), phase difference ($\Delta\varphi$).
   Laws, relations: Relations between the characteristic physical quantities. Transformation of path- and time differences into phase differences. The description of pattern obtained on a screen by rotating vectors demonstrating oscillations.
   Applications: Principle of structure examination by diffraction. Abbe's equation. Phase contrast microscope.

6. Dual nature of light.
   Basic concepts: Electromagnetic waves. Photons.
   Phenomena: Light interference, polarization, birefringence, photoelectric effect.
   Physical quantities: Electric field strength (E), magnetic field strength (B), frequency (f), period time (T), wavelength (λ), light velocity (c), phase (φ), phase difference ($\Delta\varphi$), photon energy (ε).
   Laws, relations: Relations between the characteristic physical quantities, Einstein-formula.
   Applications: Polarization microscope, optical anisotropy. Photocell.

7. Particle-wave duality in case of the electron.

Basic concepts: Particle. Matter wave.
Phenomena: Cathode ray, Thomson's experiment, Davisson – Germer experiment.
Physical quantities: Momentum (p), wavelength (λ), place (x), energy (E), state function ($\psi(x, t)$)
Laws, relations: Relations between the characteristic physical quantities. de Broglie formula, Heisenberg's uncertainty relation. Propagation of the free electron: comparison with the classical explanation.
Applications: Electron microscopy.

8. Electrons in the bound state. Atomic models.

Basic concepts: Bound and free electron. Matter wave. Energy quantum and other quantized variables. Spin.
Phenomena: Rutherford's experiment, Franck – Hertz-experiment,*:* Stern–Gerlach experiment, Einstein–de Haas experiment.
Physical quantities: Momentum (p), wavelength (λ), place (x), energy (E), angular momentum (L), quantum numbers (n, l, m_l, m_s).
Laws, relations: Relations between the characteristic physical quantities. Bohr formula, de Broglie formula, Pauli's principle.
Applications Interpretation of the covalent bond. The periodic table. Singlet and triplet states. Transitions between electronic states (luminescence, MRI).

9. General description of atomic and molecular interactions.

Basic concepts: Attractive and repulsive interactions. Covalent and van der Waals radii.
Phenomena: Chemical reactions, bond formation.
Physical quantities: Potential energy (E_{pot}), bond distance (r_0), bond energy (E_k), electric dipole momentum (p).
Laws, relations: Relations between the characteristic physical quantities.
Applications: Atomic force microscopy.

10. Many-particle systems. Ideal and real gases.

Basic concepts: Microstate, interactions, translational and rotational motion, vibration, macrostate.
Phenomena: Collisions, origin of gas pressure. Sensing the temperature of gases.
Physical quantities: Place (x), velocity (υ), pressure (p), volume (V), temperature (T), amount of material (ν).
Laws, relations: Gas laws and corrections.
Applications: Breathing.

11. Boltzmann-distribution.

Basic concepts: Thermal equilibrium. Microstate, macrostate. The most probable macrostate.
Phenomena: Decrease of oxygen concentration at high altitudes. Galvanic cells.
Physical quantities: Energy (E), occupation number (n), thermal energy (kT).
Laws, relations: Relations between the characteristic physical quantities. Boltzmann formula.
Applications: Barometric altitude formula, thermal emission of metals, Nernst equation, equilibrium and velocity of chemical reactions.

12. Solids.

Basic concepts: Crystalline state, space-lattice, unit cell, energy bands, crystal lattice defects, dopants, n- and p-type semiconductors.
Phenomena: Electric conduction, insulation, transparency, manifestation of anisotropy.
Physical quantities: Width of the forbidden band ($\Delta\varepsilon$), conductivity (σ).
Laws, relations: The Boltzmann formula.
Applications: Scintillation and semiconductor detectors, microelectronics.

13. Liquid crystals.

Basic concepts: Anisotropic liquids, translational and orientational order, thermotropic and lyotropic systems.
Phenomena: Thermo- and electrooptical phenomena. Phase transitions.
Physical quantities: Temperature (T), concentration (c).
Laws, relations: Macroscopic and microscopic description of phase transitions.
Applications: Contact thermography, liquid crystal displays (LCD), liposomes. Biological membranes.

14. Interaction of light with particles (atoms and molecules)

Basic concepts: Light scattering, Rayleigh-scattering, Mie-scattering, light absorption.
Phenomena: Blue sky, sunset, white and grey clouds, transparency.
Physical quantities: Light intensity (J), electric dipole momentum (p), absorbance (A).
Laws, relations: Attenuation of light intensity passing through a medium. Dependence of scattered light intensity on wavelength. Lambert–Beer-law.
Applications: Measurement of static light scattering and absorption, absorption spectrometry, determination of concentration. Dark field microscope.

15. Thermal radiation.

Basic concepts: Absolute black body, electromagnetic radiation.
Phenomena: Shadow of candle, color and brightness of the incandescent lamp.
Physical quantities: Radiant emittance (M), absorption coefficient (α), temperature (T), wavelength belonging to maximum radiant emittance ($\lambda_{\max}$).
Laws, relations: Prévost-law, Kirchhoff's law of thermal radiation, Stefan-Boltzmann law, Wien's displacement law.
Applications: Light sources, telethermography, heat loss of the human body.

16. Fundamentals of luminescence.

Basic concepts: Ground state, excited state, singlet and triplet states, vibrational levels, light emission, fluorescence, phosphorescence, Jablonski-diagram.
Phenomena: Fireflies and visibility vests. Light emission by tooth enamel and white t-shirts (in disco, e.g.).
Physical quantities: Light intensity (J), lifetime of excited state (τ), fluorescence quantum yield (Q_F).
Laws, relations: Relations between the characteristic physical quantities, Kasha's rule, Stokes-shift.
Applications: Fluorescent labeling, emission spectrometry, fluorescence microscopy.

17. Light amplification. Laser function.

Basic concepts: Spontaneous and induced emission, saturation of a state, population inversion, optical pumping, optical resonator.
Phenomena: The light beam of a laser pointer.
Physical quantities: Einstein coefficients (A, B), number of transitions (ΔN), light intensity (J).
Laws, relations: Ratio of electrons in different states according to Boltzmann distribution. Change of light intensity passing through a medium with population inversion. Resonance condition.
Applications: Laser surgery, dermatology, ophthalmology.

18. Atomic nucleus, nuclear radiations.

Basic concepts: Proton, neutron, nuclear forces, unstable nuclei, α-, β^--, β^+- and γ-particles, neutrino, antineutrino.
Phenomena: Mass defect, α-, and β-decay, origin of γ-radiation, annihilation.
Physical quantities: Bond energy (E_k), particle energy (ε).
Laws, relations: Conservation laws. Characteristics and explanation of particle spectra.
Applications: Radioactive labeling.

19. Radioactive isotopes, the decay law.

Basic concepts: Proton, neutron, unstable nuclei, α-, β^--, β^+- and γ-particles.
Phenomena: radioactive decay.
Physical quantities: Number of undecayed atoms (N), activity (Λ), decay constant (λ), average lifetime (τ), half-life (T).
Laws, relations: Decay law in differential and integral forms.
Applications: Radioactive labeling, diagnostics.

20. Interaction of nuclear radiations and their effects in the living organism.

Basic concepts: α-, β^--, β^+- and γ-particles, proton, neutron, Bragg-peak.
Phenomena: Direct ionization, indirect ionization, photoeffect, Compton-effect, pair production.
Physical quantities: Linear ion density (n/l), stopping power (s), particle energy (ε), effective range (x).
Laws, relations: Relations between the characteristic physical quantities. Energy conservation.
Applications: Radiological protection, radiotherapy.

21. Dosimetry, dose concepts.

Basic concepts: Ionizing radiations, danger, risk.
Phenomena: Direct and indirect radiation effect, stochastic and deterministic effect, acute and chronic radiation injury.
Physical quantities: Absorbed dose (*D*), exposure (*X*), radiation weighting factor (w_R), equivalent dose (*H*), tissue weighting factor (w_T), effective dose (*E*).
Laws, relations: Relations between the characteristic physical quantities ALARA-principle.
Applications: Radiological protection.

22. Nuclear measurement technique. Dose measuring devices.

Basic concepts: Scintillation counter, gas ionization chamber, Geiger-Muller counter, thermoluminescent dosimeter.
Phenomena: Scintillation, ionization, thermoluminescence.
Physical quantities: Ionization voltage (*U*), ionization current (*I*), particle energy (ε).
Laws, relations: Relations between the characteristic physical quantities.
Applications: Detectors of diagnostic devices, gamma camera, radiation protection.

23. Isotope diagnostics. Selection principles of isotopes.

Basic concepts: tracing with isotopes, in vitro and in vivo examinations, radiopharmaceuticals.
Phenomena: α-, β-, and γ-radiation, β^+-decay, annihilation, scintillation.
Physical quantities: Activity (*Λ*), physical, biological and effective half-lives, particle energy (ε), .
Laws, relations: Relations between the characteristic physical quantities, extension of decay law.
Applications: Gamma camera, static and dynamic examinations, planar scintigraphy, SPECT, PET.

24. Biological signals, signal processing.

Basic concepts: Analog and digital signals, periodic signals and pulses, detectors, transducers, noise, feedback, frequency response characteristics. Sampling.
Phenomena: Voltage division, amplification, filtering.
Physical quantities: Voltage (*U*), current (*I*), capacity (*C*), voltage gain (A_U), power gain (A_P), feedback factor (β).
Laws, relations: Relations between the characteristic physical quantities, Ohm's law, Fourier theorem, Shannon - Nyquist theorem.
Applications: Voltage divider, RC-circuit, diode, amplifier, LCD.

(II. semester)

25. Production and characterization of X-radiation, fundamentals of X-ray diagnostics.
Basic concepts: X-ray tube, X-ray spectrum, particle accelerators, hard and soft X-rays, filters, contrast materials, electronic X-ray image amplifier, summation image.
Phenomena: Cathode-ray, Bremsstrahlung and characteristic radiation, X-ray absorption, microscopic interactions, photoeffect, Compton-effect.
Physical quantities: Anode current (I_{anode}), anode voltage (U_{anode}), minimum wavelength (λ_{min}), X-ray power (P_X), atomic number (Z), efficiency (η), attenuation coefficients (μ, τ, σ), Hounsfield-unit (HU).
Laws, relations: Relations between the characteristic physical quantities related to X-ray emission and absorption, Duane – Hunt-law.
Applications: X-ray diffraction, X-ray imaging, DSA, traditional tomography, CAT-scan.

26. Flow of fluids and gases.
Basic concepts: Streamlines, laminar and turbulent flow, stationary flow, ideal and real fluids, Newtonian fluids.
Phenomena: Turbulence, pressure drop due to flow, internal friction.
Physical quantities: Volumetric flow intensity (I_V), frictional force (F), viscosity (η), velocity drop ($\Delta v/\Delta h$).
Laws, relations: Relations between the characteristic physical quantities, continuity equation, Bernoulli's law, Newton's law of friction.
Applications: Systemic circulation, plasma skimming.

27. Flow in tubes.
Basic concepts: Velocity profile, pressure drop, pulsed flow, critical Reynolds number, non-newtonian fluid.
Phenomena: Pressure drop in real flowing fluid, turbulence.
Physical quantities: Volumetric flow intensity (I_V), pressure drop ($\Delta p/\Delta l$), viscosity (η), flow resistance of the tube (R_{tube}), critical velocity (v_{crit}).
Laws, relations: Relations between the characteristic physical quantities, Hagen – Poiseuille-law.
Applications: Circulation, breathing.

28. Diffusion. Osmosis.
Basic concepts: Thermal motion, diffusion, osmotic equilibrium.
Phenomena: Brownian motion, Fick's experiment.
Physical quantities: Particle flow intensity (I_N), particle flow density (J_ν), concentration drop ($\Delta c/\Delta x$), diffusion coefficient (D), osmotic pressure (p_{osm}).
Laws, relations: Relations between the characteristic physical quantities, Fick's laws, generalized continuity equation, van't Hoff's law.
Applications: Dissolution, purgative salts, isotonic solution.

29. Microscopic description of diffusion.
Basic concepts: Thermal motion, random walk.
Phenomena: Brownian motion, the $KMnO_4$ experiment.
Physical quantities Mean free path (l), drift speed (v_{drift}), mobility (u), viscosity (η), average displacement ($R_{\text{avg}}(t)$), concentration distribution ($c(x, t)$), diffusion coefficient (D).
Laws, relations: Relations between the characteristic physical quantities, Stokes' law, Einstein – Stokes-law.
Applications: Gas exchange between blood and alveoli.

30. Termodiffusion and heat convection.
Basic concepts: Diffusion away from thermal equilibrium.
Phenomena: Ludvig – Soret effect.
Physical quantities Temperature drop ($\Delta T/\Delta x$), particle flow density (J_ν), energy flow density (J_E).
Laws, relations: Relations between the characteristic physical quantities, Fourier's law.
Applications: Chilling of the human body.

31. Unified description of transport processes.
Basic concepts: Thermodynamic system. Extensive and intensive quantities. Cross effect.
Phenomena: Pulsed transport, particle, charge, and energy transport processes.
Physical quantities Flux density (J), thermodynamic force (X), conductivity coefficient (L).
Laws, relations: Relations between the characteristic physical quantities, Onsager's linear relationship.
Applications: Diffusion, thermodiffusion, heat conduction, electric conduction.

32. Laws of thermodynamics.

Basic concepts: Thermodynamic system. Equilibrium. Energy conservation, direction of thermodynamic processes.
Phenomena: Spontaneous processes. Irreversible processes.
Physical quantities Internal energy (E), pressure (p), volume (V), temperature (T),.heat (Q_E), chemical potential (μ), electrochemical potential (μ_e), amount of material (ν), electric potential (φ), charge (Q), ion value (z), Faraday constant (F), entropy (S).
Laws, relations: Relations between the characteristic physical quantities, 0^{th}, 1^{st}, 2^{nd}, 3^{rd} law of thermodynamics.
Applications: Efficiency, chemical reactions.

33. Statistical interpretation of entropy. Thermodynamic potential functions.

Basic concepts: Macrostate, microstate. Potential energy.
Phenomena: Properties of entropy. Direction of thermodynamic processes.
Physical quantities: Thermodynamic probability (Ω), entropy (S), enthalpy (H), free energy (F), free enthalpy (G), pressure (p), volume (V), temperature (T), chemical potential (μ), material quantity (ν).
Laws, relations: Relations between the characteristic physical quantities, Gibbs–Duhem-relation.
Applications: Boltzmann-distribution. Hess' law.

34. Bioelectric phenomena.

Basic concepts: Stimulus, action potential, electric model of membrane.
Phenomena: Transport processes across biological membrane. Passive and active transport. Changes of membrane potential. Hyperpolarization, hypopolarization, depolarization, propagation of the action potential.
Physical quantities: Flux density (J_ν), concentration drop ($\Delta c/\Delta x$), permeability constant (p_m), membrane potential (φ^{II} - $\varphi^{I} = U$), time constant (τ_m), space constant (λ).
Laws, relations: Relations between the characteristic physical quantities, Donnan-equilibrium, Nernst-equation, Goldman–Hodgkin–Katz-equation.
Applications: Electric signals on the body surface, ECG, EEG, EMG, patch clamp, voltage clamp.

35. Electric signals and methods in biomedicine.

Basic concepts: Electric square pulses, multivibrators, stimulus characteristics, rheobase, chronaxie, sine wave oscillator.
Phenomena: Timing with the RC circuit. Galvani's experiment: evoking muscle contraction with electric pulse.
Physical quantities: Electric charge (Q), electric field strength (E), voltage (U), current intensity (I), resistence (R), resistivity (ρ), conductivity (σ), pulse duration (τ), capacity (C), self inductance (L).
Laws, relations: Relations between the characteristic physical quantities, mathematical approach to stimulus characteristics. Calculation of pulse energy and heat.
Applications: Pacemaker, defibrillator, thermal therapy devices, electric surgery.

36. Generation and characterization of ultrasound. Ultrasound diagnostics and therapy.

Basic concepts: Sine oscillator, mechanical wave, sound and ultrasound, coupling medium.
Phenomena: Direct and inverese piezoelectric effects, absorption, reflection, Doppler-effect.
Physical quantities: speed of propagation (c), frequency (f), wavelength (λ), intensity (J), acoustic impedance (Z), damping (α), reflectivity (R).
Laws, relations: Relations between the characteristic physical quantities. Pulse-echo principle. Calculation of Doppler-shift.
Applications: Ultrasonic imaging, imagng modes, Doppler-method. Therapeutic ultrasound applications.

37. General laws of perception.

Basic concepts: Receptor, stimulus, adequate stimulus, sensation, sensory organs.
Phenomena: Adaptation, localization.
Physical quantities: receptor potential (U), frequency of action potential (f), parameters of stimulus and sensation (Φ, Ψ).
Laws, relations: Psychophysical laws, Weber – Fechner-law, Stevens'-law.
Applications: Vision, hearing, sensation of smell and pain.

38. Visual sensation.

Basic concepts: Retina, cones, rods, fovea, electromagnetic spectrum, visible light, colors.
Phenomena: Sensitivity of the human eye, color vision, optical illusions.
Physical quantities: wavelength of light (λ), light intensity (J), phase (φ), diameter of the Airy-disk (d).
Laws, relations: Optical and biological resolution of the eye, molecular process of light sensation.
Applications: Color mixing, color coding, night blindness.

39. Auditory sensation.

Basic concepts: Outer, middle, and inner ear, pitch, octave, sinusoidal (pure) sound, tone, harmonics, loudness.
Phenomena: Sensitivity of the human ear. Tone. Beat.
Physical quantities: Frequency (f), intensity (J), intensity level (n), loudness level (H_{phon}, H_{son}).
Laws, relations: Pressure amplification in the middle ear, frequency discrimination and signal amplification in the inner ear. Theories of hearing.
Applications: Audiometry, hearing impairment.

40. Biophysics of water.

Basic concepts: Molecular structure, phase, phase diagram, volumetric mesh structure through H-bonds.
Phenomena: Blue color of the sea, symmetry of snowflakes, life under the surface of frozen lake, running of water striders on water surface.
Physical quantities: surface tension (α), density (ρ), dielectric constant (ε), heat of melting (L_{o}) and boiling (L_{f}).
Laws, relations: Explanation of the anomalous properties of water
Applications: Hydration, hydrophobic interaction, microwave oven.

41. Biophysical approach to biological macromolecules.

Basic concepts: Monomer, polimer, primary and secondary bonds, structural hierarchy, elasticity, stability.
Phenomena: Shape fluctuations of polimer chains, protein denaturation, protein folding.
Physical quantities: contour length (L), persistence length (L_p), end-to-end distance (R), pitch of helix (h), Gibb's free energy (G).
Laws, relations: Boltzmann-distribution, square root law – analogy with random walk. Levinthal's paradox.
Applications: Mechanical manipulation of single molecules.

42. Motor proteins.

Basic concepts: Structure and types of motor proteins. Linear and rotational motors.
Phenomena: Duty cycle, power-stroke, ATP-hydrolysis cycle.
Physical quantities: force (F), working distance (δ), unloaded velocity (v).
Laws, relations: duty ratio (r), processivity.
Applications: Intracellular motion, vesicular transport, transcription.

43. Striated muscle function

Basic concepts: Structure of the sarcomere, myofilaments.
Phenomena: Twitch, tetanus, types of contraction, excentric and concentric muscle function.
Physical quantities: shortening velocity (v), muscle work (W), power (P).
Laws, relations: force – velocity relation, Fenn-effect, sliding filament model, cross-bridge model.
Applications: Force generation and shortening velocity of fast and slow fibers.

44. Biomechanics. Cytoskeletal system.

Basic concepts: Monomer, polymer, thin and intermediate filaments, microtubules.
Phenomena: Elastic and plastic shape changes, viscoelasticity, stress relaxation, hysteresis.
Physical quantities: mechanical stress (σ), deformation (ε), Young-modulus (E), viscosity (η), contour length (L), persistence length (L_p), end-to-end distance (R).
Laws, relations: Hooke's law, stress – strain curve, polymerization of cytoskeletal proteins.
Applications: Biomechanical role of the intervertebral disk, elasticity of arteries, intracellular functions of cytoskeletal filaments.

45. Investigation of biomolecular structure: applications of luminescence.
Basic concepts: Luminescence spectroscopy, fluorophore, donor, acceptor. Confocal and two-photon microscopy.
Phenomena: Energy transfer, luminescence quenching, multiphoton phenomenon.
Physical quantities: fluorescence lifetime (τ), quantum yield (Q), transfer efficiency (E), donor–acceptor-distance (R).
Laws, relations: Relations between the characteristic physical quantities.
Applications: FRET as molecular ruler, in vivo microscopy.

46. Investigation of biomolecular structure: mass spectrometry.
Basic concepts: Atomic mass, molecular mass, magnetic quadrupole.
Phenomena: Production of gaseous molecules from the sample, ionization, electron ionization, laser desorption.
Physical quantities: mass (m), electric field (E), time of flight (t).
Laws, relations: motion of charged particle in electric and magnetic field.
Applications: Fast diagnostics by mass spectrometry.

47. Investigation of biomolecular structure: light scatter, absorption spectrometry, infrared spectroscopy.
Basic concepts: Static and dynamic light scatter, fluctuation, autocorrelation function, monochromator, Fourier-transformation.
Phenomena: Rayleigh-scattering, light absorption, molecular vibrations, interference.
Physical quantities: Intensity (J), absorbance (A), frequency (f), Wavenumber ($1/\lambda$).
Laws, relations: Relations between the characteristic physical quantities. Lambert–Beer-law.
Applications: Laboratory diagnostics. Following of protein aggregation by FTIR spectroscopy.

48. Investigtion of biomolecular structure: radio spectroscopies, ESR, NMR, fundamentals of MRI.
Basic concepts: Excitation, spectrum, relaxation.
Phenomena: Stern-Gerlach-experiment, splitting of energy levels in magnetic field, resonance.
Physical quantities: parameters of the magnetic field (H, B), magnetic momentum (M), photon energy (ε), T1 and T2 relaxation times.
Laws, relations: Dependence of energy on magnetic field strength, resonance condition (absorption), relaxation processes.
Applications: ESR spectroscopy and spin labeling, NMR spectroscopy, MRI.

49. Biophysics of heart function. Physical basis of ECG.
Basic concepts: Heart chambers, valves, large vessels, stimulus conduction system of the heart.
Phenomena: Muscle contraction, cyclic function of the heart, depolarization, repolarization.
Physical quantities: pressure (p), volume (V), static and dynamic work (W), electric dipole momentum (p), electric field strength (E), potential (φ), voltage (U), integral vector.
Laws, relations: Work of the heart, characteristics of the ECG.
Applications: Change of physical parameters in pathological states.

50. Biophysics of blood circulation.
Basic concepts: Basic features of the circulatory system, elastic vessels, suspension, corpuscular elements of blood.
Phenomena: Stationary, laminar and turbulent flow, behavior of non-newtonian (anomalous) fluids. Roleaux formation, deformation of red blood cells by external forces.
Physical quantities: viscosity (η), total cross-sectional area (A_T), flow velocity (v), pressure (p).
Laws, relations: Continuity equation, Young–Laplace-equation, Hagen–Poiseuille-law, Fahreus-Lindquist effect, variation of physical parameters along the circulatory system.
Applications: Change of physical parameters in pathological states. Auxiliary forces of blood circulation.

51. Biophysics of respiration.

Basic concepts: Respiratory system, gas exchange surface, conduction zone, gas exchange zone, circulatory system, elastic vessels.

Phenomena: Laminar and turbulent flow, non-stationary flow.

Physical quantities: minute volume (V), transmural pressure (p_{tm}), partial pressure (p_{O2}), distensibility ($C = \Delta V/\Delta p$), surface tension (α).

Laws, relations: Similarities between respiration and circulation (flow of gases and liquids). Continuity equation, gas laws, Young–Laplace-equation, Henry's law, Dalton's law, Hagen–Poiseuille-law, Fick's laws, respiratory work.

Applications: Change of physical parameters in pathological states.

52. Biophysical basis of physical examination.

Basic concepts: Inspection, palpation, percussion, auscultation, sound, noise, murmur, beat.

Phenomena: Color change of the skin, pitting, drum-like sound, light absorption, propagation of sound, elastic deformation.

Physical quantities: color (f), compressibility (κ) , viscosity (η), Reynolds-number (Re).

Laws, relations: Lambert-Beer-law, spring-dashpot model, Bernoulli's law, generation of cardiac and respiratory sounds and murmurs.

Applications: Demonstration of some physical symptoms: cyanosis, icterus, erythema, edema, Korotkow's sound.

Practice questions on the final exam 2016/17

I. semester

1. Microscopy I.
   Theoretical background:
   - types of optical lenses, parameters of them
   - image formation of convex lenses
   - lens laws
   - image formation and magnification of microscope
   - resolving power of microscope (Abbe's principle)

   Quantities to be determined based on the given data:
   calibration value of eyepiece scale and size of the object.

2. Refractometry
   Theoretical background:
   - law of light refraction, definition of index of refraction
   - critical angle, total reflection
   - formation of Snell circle
   - factors influencing the value of index of refraction
   - parts and function of Abbe-refractometer

   Quantities to be determined based on the given data after proper graphical representation:
   the unknown concentrations.

3. Light absorption
   Theoretical background:
   - derivation of Lambert-Beer law from the absorption law
   - absorbance, transmittance and the relation of them
   - absorption spectrum and the information available from it
   - parts of absorption spectrometer
   - application of absorbance measurement in laboratory diagnostics

   Quantities to be determined based on the given data after proper graphical representation:
   photon energy belonging to electron transition (in eV units)

4. Polarimetry
   Theoretical background:
   - linearly polarized, circularly polarized light and the connection between them
   - definition and interpretation of optical activity

- Biot-law, specific rotation
- parts and function of polarimeter

Quantities to be determined based on the given data:
the type of given sugar and the unknown concentration.

5. Optics of the eye

Theoretical background:
- refractive media and image formation of the eye
- accommodation
- refractive disorders of eye and the way for correction of them
- limiting angle of vision, visual acuity (visus), factors influencing the visual acuity
- distribution of photoreceptors on the retina

Quantities to be determined based on the given data:
accommodation power and visual acuity.

6. Nuclear medicine

Theoretical background:
- parts of scintillation counter
- possible processes happening in the scintillation crystal
- processes happening in the photomultiplier
- signal selection, function of the discriminator, sources of noise pulses
- optimal setting of scintillation counter

Quantities to be determined based on the given data after proper graphical representation:
the optimal discrimination level.

7. Gamma-absorption

Theoretical background:
- attenuation law of radiation, attenuation coefficient, mass attenuation coefficient
- processes of attenuation on the atomic scale (photoeffect, Compton-scattering, pair production, elastic scattering)
- the dependence of mass attenuation coefficients due to different processes on the photon energy
- viewpoints of radiation protection

Quantities to be determined based on the given data after proper graphical representation:
D, μ, $\mu_{m,}$ for all the absorbents and ε, τ_{mPb}, σ_{mPb}.

8. Resonance

Theoretical background:
- elastic deformation, Hooke's law
- harmonic oscillation
- undamped and damped free oscillation
- driven oscillation, resonance
- effect of external force (depending on the distance) on the driven oscillation (working principle of AFM)

Quantities to be determined based on the given data after proper graphical representation:
the spring constant.

9. Skin impedance

Theoretical background:
- definition and components of impedance
- electric model of the skin and the possible simplifications on the model
- frequency dependence of capacitive reactance, approximation of skin impedance in case of low and high frequencies
- practical applications of impedance measurement

Quantities to be determined based on the given data:
specific resistance and specific capacity of the skin.

II. semester

1. Dosimetry
   Theoretical background:
   - the most important basic concepts in dosimetry
   - function of thermoluminescent dosimeter
   - application of the ionization chamber as dose rate measuring device
   Quantities to be determined based on the given data after proper graphical representation:
   Voltage – current diagram of the ionization chamber. Name the ranges of the diagram and determine the exposure rate and absorbed dose rate in air.

2. Coulter-counter
   Theoretical background:
   - parts and function of the equipment
   - function of ID, DD and multichannel analyzer
   - additional methods for counting different types of blood cells
   Quantities to be determined based on the given data after proper graphical representation:
   Calibration value, unknown blood cell concentration, RBC discrimination level

3. Diffusion
   Theoretical background:
   - phenomenon of diffusion and its mathematical description: Fick's I. and II. law.
   - solution of Fick's II. law in case of concrete experimental conditions (to be listed)
   - determination of the amount of material diffused out by the measurement of conductance
   Quantities to be determined based on the given data after proper graphical representation:
   The diffusion coefficient and the Stokes radius of hydrated K^+ and Cl^- ions

4. Amplifier
   Theoretical background:
   - gain, gain level
   - frequency response curve of the amplifier
   - negative feedback
   - advantages and disadvantages of feedback
   Quantities to be determined based on the given data after proper graphical representation:
   The maximum gain level, cut-off frequencies of the transfer band. Can it be used for the amplification of ECG signal?

5. X-ray I.
   Theoretical background:
   - parts and function of the X-ray tube
   - production, spectrum and diagnostic energy range of X-radiation
   - power of Bremsstrahlung and efficiency of X-ray tube
   Based on the given spectra make a graph, which proves Duane–Hunt-law.

6. X-ray II.
   Theoretical background:
   - attenuation of X-ray intensity
   - application of filters in X-ray diagnostics
   - atomic processes of attenuation, dependence of their mass attenuation coefficients on the photon energy
   - explain which photonenergies are the best for X-ray diagnostics
   Based on the given data make a graph that shows the relationship between the mass attenuation coefficient of photoeffect and the atomic number of the absorbent.

7. Gamma energy
Theoretical background:
- energy transformations in the scintillation counter, energy selectivity
- possible applications of discriminators
- spectrum of gamma radiation and the pulse amplitude spectrum
- give an example for dual isotope labeling, and explain its advantage
Quantity to be determined based on the given data after proper graphical representation:
The unknown photon energy

8. Audiometry
Theoretical background:
- physical characteristics of sound
- the human hearing range, threshold of hearing, threshold of pain
- loudness, loudness level and the connection between them
- interpretation of the audiogram
Based on the given data construct the hearing threshold curve and the audiogram

9. Pulse generator
Theoretical background:
- characteristic parameters of square pulses
- types of multivibrators, practical application of them
Determine the parameters of the pulse series shown on the attached graph (amplitude, pulse duration time, period time, frequency, duty cycle, and the energy of one pulse)

10. ECG
Theoretical background:
- explain the formation of the ECG curve, and its components
- types of ECG leads
- Einthoven-triangle, integral vector
- parts of the ECG equipment, differential amplifier
Based on the attached ECG curves construct the integral vector and determine the heart rate

11. Flow
Theoretical background:
- stationary and pulsed, laminar and turbulent flow
- Hagen–Poiseuille-law and the conditions of its validity
- changes of pressure, cross section and flow velocity in the circulatory system
- electrical model of the vascular system (analogies)
Based on the given data determine the number of branches in part B and C of the model

12. Sensor
Theoretical background:
- model of the sensory system
- stimulus, receptor potential, action potential, sensation
- explain the role of voltage – frequency conversion in the sensation process
- psychophysical laws
Based on the given data after proper graphical representation whether the model supports the Weber–Fechner or the Stevens-law.

13. CAT-scan
Theoretical background:
- X-ray density and the Hounsfield scale
- comparison of summation image and CAT-scan image
- theoretical background of the CAT-scan image formation
Based on the given data determine the position of absorbents in the model.