Theoretical questions – final

1 Types of radiations.
2 Dependence of irradiance on distance from the source.
3 Fundamentals of geometric optics.
4 Radiometric quantities.
5 Attenuation law.
6 Fermat’s principle.
7 Law of refraction.
8 Law of reflection.
9 Total internal reflection and its applications.
10 Image formation on a curved surface.
11 Principal light rays.
12 Lens combinations.
13 Refractive power.
14 Lens equation.
15 Image formation by the light microscope.
16 Rules of image formation.
17 Concepts of magnification and angular magnification.
18 Magnification in the light microscope.
19 Oscillations.
20 Diffraction on an optical grating.
21 Polarization of light.
22 Types of waves.
23 Limit of resolution of the light microscope.
24 Phase contrast microscope.
25 Huygens-Fresnel principle.
26 Polarization microscope.
27 Wave interference.
28 Wave diffraction.
29 Interpretation of the color of light.
30 Wave nature of light.
31 Dual nature of light.
32 Matter waves.
33 The electromagnetic spectrum.
34 The photoelectric effect.
35 The electron microscope.
36 Photon energy, the eV scale.
37 Interpretation of momentum of light: optical tweezers.
38 Models of the atom (Dalton, Thomson).
39 Wave nature of the electron.
40 The bound electron, quantum numbers.
41 Bohr's atomic model.
42 Heisenberg’s uncertainty principle.
43 Physical foundations of the periodic table.
44 Franck-Hertz experiment.
45 Potential energy of interatomic interactions.
46 Electronegativity.
47 Scanning probe microscopy.
48 Primary and secondary bonds.
49 Resolving power of the atomic force microscope.
50 The Ideal gas.
51 Maxwell-Boltzmann velocity distribution.
52 Applications of the Boltzmann-distribution I. : Nernst equation.
53 The real gas.
54 State equation of real gases.
55 Applications of the Boltzmann-distribution II.: equilibrium and rate of chemical reactions. (The Arrhenius plot).
56 Macrostate and microstate in thermodynamics.
57 Boltzmann distribution.

58 Boltzmann’s definition of entropy.
59 Kinetic gas theory.
60 Pressure of ideal gases.
61 Applications of the Boltzmann-distribution III.: barometric formula.
62 Applications of the Boltzmann-distribution IV.: electric conductivity of semiconductors.
63 The crystalline state (unit cell, crystal defects).
64 Optical properties of crystalline materials.
65 Thermotropic liquid crystals.
66 Energy levels of electrical insulators.
67 The function of the semiconductor diode.
68 Lyotropic liquid crystals.
69 Energy levels of electrical conductors.
70 The liquid state.
71 Electro- and thermooptical phenomena in liquid crystals.
72 Energy levels of intrinsic semiconductors.
73 Types of doped semiconductors.
74 Light scattering (Rayleigh and Mie).
75 The Lambert-Beer law.
76 Properties of the absorption spectrum.
77 Turbidimetry and nephelometry.
78 Dynamic light scattering.
79 Measurement of the absorption spectrum.
80 Energy levels of atoms and molecules: the Jablonski diagram.
81 Thermal radiation.
82 Planck’s radiation law.
83 Light sources based on thermal radiation.
84 Absolute black body.
85 Emission spectrum of the absolute black body.
86 Medical applications of thermal radiation.
87 Kirchhoff’s law.
88 The Stefan-Boltzmann law.
89 Wien’s displacement law.
90 Luminescence: excitation and relaxation.
91 Kasha’s rule.
92 The fluorescence spectrometer.
93 Fluorescence.
94 Luminescence spectra.
95 FRET.
96 Phosphorescence.
97 Stokes-shift.
98 FRAP.
99 Notable transitions of luminescence: vibrational relaxation, intersystem crossing.
100 Quantum yield of luminescence.
101 Fluorescence microscopy.
102 Luminescence lifetime.
103 Laser: induced emission.
104 Laser: the optical resonator.
105 Types of lasers.
106 Laser: population inversion.
107 Properties of laser light.
108 Applications of lasers.
109 Structure of the atomic nucleus.
110 Alpha decay.
111 Energy spectra of alpha, beta and gamma radiations.
112 Stability of the atomic nucleus.
113 Beta negative decay.
114 Production of isotopes.
115 Isotopes.
116 Beta positive decay.

117 Types of radioactive decay.
118 Gamma decay.
119 Activity.
120 Interaction of alpha radiation with matter.
121 Interaction of gamma radiation with matter I: photoeffect.
122 Differential and integral forms of the decay law.
123 Interaction of beta negative radiation with matter.
124 Interaction of gamma radiation with matter II: Compton-scatter.
125 Half-life and average lifetime of an isotope.
126 Interaction of beta positive radiation with matter.
127 Interaction of gamma radiation with matter III: pair production.
128 Neutron radiation, proton radiation, the Bragg-peak.
129 Scintillation counter I.: the scintillation crystal.
130 The gas ionization chamber.
131 Thermoluminescent dosimetry.
132 Scintillation counter II.: the photomultiplier tube.
133 The Geiger-Müller counter.
134 Semiconductor detectors in dosimetry.
135 Physical, chemical and biological phases of radiation effects.
136 The absorbed dose.
137 Converting exposure in air to absorbed dose in tissue.
138 The stochastic radiation effect.
139 The exposure.
140 Weighting factors in dosimetry.
141 The deterministic radiation effect.
142 The equivalent dose.
143 ALARA-principle.
144 The direct and indirect effects of ionizing radiations.
145 The effective dose.
146 Typical dose values and dose limits.
147 The dose rate.
148 Information obtained by isotope diagnostics.
149 Principles of selecting the isotope for diagnostics according to half-life.
150 Parts and function of Tc-generator.
151 Cost-benefit principle in isotope diagnostics.
152 Principles of selecting the isotope for diagnostics according to radiation type and energy.
153 Definition of the radiopharmaceutical.
154 Parts and function of gamma-camera.
155 Determination of the biological half-life of an organ.
156 Relative depth dose.
157 Scintigraphy.
158 SPECT.
159 Teletherapy, geometric viewpoints.
160 Interpretation of a typical isotope accumulation curve.
161 Parts and working principle of PET.
162 Role of collimators in radiation therapy, gamma-knife.
163 Multimodal imaging: PET/CT and SPECT/MRI.
164 Principles of brachytherapy.
165 Classification and comparison of signals.
166 Typical frequency and amplitude ranges of biological signals.
167 Feedback amplifiers.
168 Fourier-theorem for periodic and aperiodic signals.
169 Parts and function of filtering circuits.
170 Digitalization of analog signals.
171 Shannon-Nyquist theorem.
172 Processing of pulse signals.
173 Typical diagnostic wavelength and photon energy range of x-ray.
174 Power and efficiency of the x-ray tube.
175 The Duane-Hunt-law.

176 Structure and function of the x-ray tube.
177 Spectrum of Bremsstrahlung.
178 Production of characteristic x-rays.
179 Mechanisms and energy dependence of x-ray absorption.
180 X-ray contrast media.
181 CAT-scan: Principles, generations.
182 The x-ray summation image.
183 X-ray image amplifier.
184 CAT-scan: image reconstruction.
185 DSA.
186 Hounsfield unit, windowing in CAT scan.
187 Production of high-energy x-rays.
188 Volumetric flow rate, stationary flow.
189 Bernoulli's law, plasma skimming.
190 Stokes' drag law.
191 Laminar and turbulent flow.
192 Real fluids: Newton's law of friction.
193 Hagen-Poiseuille-law, flow resistance.
194 Continuity equation.
195 Reynolds-number, critical velocity.
196 Determinants of blood viscosity.
197 Basics of diffusion: Concepts, thermal motion.
198 Fick's I. law.
199 Thermodiffusion.
200 Brownian motion. Random walk.
201 The diffusion coefficient. Einstein-Stokes-equation.
202 Heat transport, Fourier's law.
203 Physical quantities used for describing the transport of matter.
204 Gas exchange between blood and alveoli.
205 Osmosis, osmotic pressure, osmolarity.
206 Fick's II. law.
207 Fundamentals of thermodynamics I.: types of systems, the human body as a thermodynamic system.
208 Fundamentals of thermodynamics II.: change of internal energy.
209 The I. law of thermodynamics and its applications for biological systems.
210 Fundamentals of thermodynamics III.: types of energies, internal energy and its components.
211 Extensive and intensive quantities and their relations.
212 Entropy and its connections with order, thermal and configurational entropy.
213 The II. law of thermodynamics, direction of spontaneous processes.
214 The III. law of thermodynamics.
215 Direction of processes in isolated, isothermal, and isothermal-isobaric systems.
216 Isobaric, isothermal, isothermal-isobaric systems.
217 Equilibrium conditions of different thermodynamic systems.
218 Thermodynamic potentials.
219 Matter transport through the cell membrane.
220 The transport model and the Goldman-Hodgkin-Katz-equation.
221 Changes in the membrane potential as the function of time.
222 Resting transmembrane potential.
223 Electric model of the membrane.
224 Changes in the membrane potential as the function of space.
225 Diffusion of ions across the membrane, permeability.
226 The Donnan-equilibrium.
227 Properties of the action potential.
228 Propagation of the action potential, refractory period and its role.
229 Electric signals measured on the body surface for diagnostic purposes.
230 Electrochemical potential.
231 Ion currents during action potential.
232 Sound as a wave.
233 Acoustic impedance, reflection of sound, reflectivity.

234 Imaging modes in sonography.
235 Generation and detection of ultrasound.
236 The Doppler-effect, the Doppler-shift.
237 Effects of ultrasound, therapeutic applications.
238 Absorption of ultrasound.
239 The pulse-echo principle.
240 Propagation of ultrasound in air and in the body.
241 Structure and properties of water.
242 Structure of biopolymers.
243 Structure and elasticity of DNA.
244 Anomalous behavior of water.
245 Structural hierarchy of proteins.
246 Phase diagram of water.
247 Biopolymer elasticity.
248 Protein-stabilizing interactions.
249 Protein folding.
250 Steps of sensory signal transduction.
251 Photoreceptors of the retina.
252 Biophysics of hearing I.: the outer ear.
253 Information coding by the receptor potential.
254 Reaction steps of light sensation.
255 Biophysics of hearing II.: the middle ear.
256 Information coding by the action potential.
257 Basis of color sensing.
258 Biophysics of hearing III.: Békésy's hearing model.
259 Stevens' Law.
260 Weber-Fechner law.
261 Sensory adaptation.
262 Biophysics of hearing IV.: signal transduction in hair cells.
263 Signal amplification by hair cells.
264 The phon scale.
265 The sone scale.
266 Biomechanics I.: stress-strain diagram and its ranges.
267 Biomechanics IV.: Laplace-Frank-equation.
268 Viscoelasticity I.: mechanical model
269 Biomechanics II.: Hooke’s law, Young-modulus.
270 Biomechanical characteristics of bone and enamel.
271 Viscoelasticity II.: stress-relaxation, energy dissipation.
272 Biomechanics of elastic arteries, distensibility.
273 Structure and types of motor proteins.
274 Muscle biophysics I.: twitch, summation, tetanus.
275 The sliding filament model of muscle contraction.
276 Processivity, typical force range and working distance of motor proteins.
277 Muscle biophysics II.: isometric and isotonic contraction.
278 The cross-bridge cycle of skeletal muscle myosin.
279 Muscle biophysics III.: work and power. Force-velocity curve.
280 Bragg-diffraction of X-rays.
281 Time of flight principle in mass spectrometry.
282 Determination of molecular structure by x-ray crystallography.
283 Ionization methods in mass spectrometry: electrospray, MALDI.
284 Mass spectrometry in medicine: proteomics, diagnostics, oncoknife.
285 Stern-Gerlach-experiment.
286 Macroscopic magnetization in MRI: spin-spin relaxation.
287 Spatial encoding in MRI.
288 Zeeman-effect.
289 Macroscopic magnetization in MRI: spin-lattice relaxation.
290 MRI contrast methods: proton density, T1 and T2 weighting.
291 Larmor-precession and nuclear magnetic resonance.
292 Differences between NMR and ESR spectroscopies.
293 Chemical shift.

294 Circulatory biophysics: function of the blood vessel system.
295 Pressure relations in the arterial system.
296 The cardiac cycle.
297 Changes in pressure in the circulatory system.
298 Auxiliary factors of circulation: the windkessel effect.
299 Pressure-volume relation of the heart.
300 Changes in the total cross section of vessels in the circulatory system.
301 Electrical description of heart function.
302 Work of the heart.
303 Changes in the flow velocity in the blood vessel system.
304 Respiratory biophysics I.: partial pressure, Henry's law.
305 Respiratory cycle.
306 Biophysics of physical examination I.: Inspection.
307 Box model of the human respiratory system.
308 Respiratory volumes and capacities.
309 Biophysics of physical examination II.: palpation.
310 Conductive and gas-exchange parts of the human respiratory sytem.
311 Biomechanics of respiration (compliance, obstructive and restrictive pathologies).
312 Biophysics of physical examination III.: percussion
313 Respiratory work.
314 Biophysics of physical examination IV.: auscultation.

Practice questions – final

1 How does refractive power of a lens change if its radius of curvature decreases?
2 How does refractive power of a lens change if its radius of curvature increases?
3 What is radius of curvature in case of a lens?
4 How does refractive power of a lens change if its index of refraction increases?
5 Calculate the refractive power of a lens with a focal distance of 25 cm.
6 Calculate the refractive power of a lens with a focal distance of 20 cm.
7 Calculate the refractive power of a lens with a focal distance of 17 mm.
8 Characterize the image of an object placed within the focal distance of a converging lens.
9 Characterize the image of an object placed between the single and the double focal distance of a converging lens.
10 Characterize the image of an object placed outside the double focal distance of a converging lens.
11 What kind of image is formed by a compound light microscope?
12 What is the total magnification of a light microscope if the objective magnification is 100x and the ocular magnification is 20x?
13 Describe the steps of the eyepiece scale calibration process.
14 What prisms are present in the Abbe-refractometer?
15 What sample can be measured with the Abbe-refractometer?
16 What is the role of Amici prism?
17 What is optical dispersion?
18 Factors influencing the value of index of refraction.
19 Formation of Snell circle.
20 How do you determine concentration by refractometry?
21 What is the refractive index of distilled water?
22 Definition of absorption spectrum.
23 What information can you obtain from an absorption spectrum?
24 How do you determine concentration by absorption photometry?
25 Define optical density (absorbance).
26 Define transmittance.
27 How much light is transmitted by a sample with an absorbance of 1?
28 Which sample transmits more light: OD=1 or OD=3? By how much?
29 How does the absorption spectrum change if the sample concentration is doubled?
30 How does the absorption spectrum change if the sample concentration is halved?

31 What is the absorption maximum characteristic of?
32 What is the function of the monochromator?
33 Define optical activity based on the refractive index.
34 Define Biot-law.
35 Describe the linearly polarized light.
36 Describe the circularly polarized light.
37 What light source is used for polarimetry and why?
38 How does optical rotation angle change if the sample tube length decreases?
39 How does optical rotation angle change if the sample concentration increases?
40 What is a chiral molecule? Provide an example.
41 Factors influencing specific optical rotation.
42 How do you determine concentration by polarimetry?
43 Refractive media of the eye. Image formation of the eye.
44 What is the refractive power of the unaccomodated human eye?
45 Which refractive surface contributes the most to the refractive power of the human eye?
46 How does the refractive power of human eye change during accomodation?
47 Describe the process of focal accomodation of the human eye.
48 How do you calculate the accomodation power of human eye?
49 How would you measure the position and diameter of the blind spot?
50 What is myopia and how do you correct it?
51 What is hyperopia and how do you correct it?
52 What is presbyopia and how do you correct it?
53 What is visual acuity and how do you measure it?
54 How did we measure the visual acuity?
55 Describe the reduced eye model.
56 Factors influencing the visual acuity.
57 Spatial distribution of photoreceptors on the retina.
58 What is the visual acuity of a patient with a limiting angle of view of 2'?
59 Parts of the scintillation counter.
60 Sources of noise in the scintillation counter.
61 How do you reduce external noise in scintillation counting?
62 How do you reduce internal noise in scintillation counting?
63 Define the integral discriminator.
64 Define the signal-to-noise ratio.
65 How to find the optimal ID setting of the scintillation counter?
66 How many electrons arrive at the PMT anode for every photoelectron if the number of the dynodes is 8 and the multiplication factor is 2.
67 Define the mass attenuation coefficient.
68 Define the surface density.
69 Define the attenuation coefficient.
70 Define the half-value layer thickness.
71 Define the tenth-value layer thickness.
72 Explain the energy dependence of mass attenuation coefficient in case of lead (graph in formula collection).
73 Compare the linear attenuation and mass attenuation coefficients for water and steam.
74 What fraction of intensity is transmitted through an absorber with a thickness twice its half-value layer thickness (x=2D).
75 What fraction of intensity is transmitted through an absorber with a thickness three times its half-value layer thickness (x=3D).
76 Harmonic oscillation (definition, equation, graph.)
77 Damped free oscillation.
78 Driven oscillation, resonance.
79 Resonance curve.
80 How does the resonance frequency change if the oscillating mass is doubled?
81 How does the resonance frequency change if the spring constant is doubled?
82 Define the eigenfrequency.
83 How do you determine the spring constant of a cantilever?

84 Definition and components of impedance.
85 Electric model of the skin.
86 Definition and unit of capacitive reactance.
87 Specific resistance of the skin.
88 Specific capacitance of the skin.
89 What component of skin impedance dominates in case of DC versus high frequency AC?
90 What is the difference between the measuring and the auxiliary electrodes in skin impedance measurement?
91 Definition and unit of capacitance.
92 Describe Ohm's law.
93 Alternating current and RMS voltage.
94 Gain and gain level of the amplifier.
95 Compare voltage and power gain.
96 What is the gain level if the voltage gain equals 1000?
97 What is the gain level if the voltage gain equals 1?
98 What is the power gain if the gain level is 3 dB?
99 Frequency response curve of the amplifier.
100 How do you determine the transfer band of an amplifier?
101 How does the bandwidth of an amplifier change with negative feedback?
102 Advantages and disadvantages of using negative feedback in an amplifier.
103 Voltage divider circuit.
104 Coulter principle.
105 Parts and functions of the Coulter-counter.
106 How does the voltage pulse amplitude depend on particle size in the Coulter-counter?
107 How do you separate the red-blood-cell versus white-blood-cell signals in a Coulter-counter?
108 How do you separate the red-blood-cell versus platelet signals in a Coulter-counter?
109 What is the role of differential discriminator in Coulter-counting?
110 Why is dilution of blood necessary in Coulter-counting?
111 What solution is used for blood dilution in Coulter-counting?
112 How does the matter flow density (flux) change if the concentration gradient is doubled?
113 Name the parameters influencing the value of diffusion coefficient.
114 What diffuses faster: a potassium ion or a virus particle?
115 How does the average distance travelled by a diffusing particle depend on time?
116 On what length scale diffusion is an effective transport process?
117 How does the the minimum wavelength of the x-ray spectrum change with increasing anode voltage?
118 How does the the minimum wavelength of the x-ray spectrum change with increasing anode current?
119 What is the maximum x-ray photon energy at 50 kV anode voltage?
120 What elements are suitable as x-ray-tube anode material?
121 What are the x-ray spectral lines characteristic of?
122 Why do we need to cool the x-ray-tube anode?
123 How does x-ray absorbance depend on the atomic number of absorber?
124 Which part of the x-ray spectrum is attenuated by filtering?
125 Which is a better x-ray absorber: Al or Ag?
126 Which attenuation mechanism dominates in x-ray diagnostics?
127 What are the parts of a gamma-radiation pulse amplitude spectrum?
128 Effect of activity on the pulse amplitude spectrum of a gamma-radiating isotope.
129 Effect of anode voltage on the pulse amplitude spectrum of a gamma-radiating isotope.
130 Compare the pulse amplitude spectra of two different gamma-radiating isotopes.
131 How can you determine the gamma energy of a radiactive isotope with a scintillation counter?
132 What type of discriminator is used for acquiring the pulse amplitude spectrum?

133 Define the human hearing range (threshold of hearing, threshold of pain, frequency limits).
134 Which one is louder: 50 Hz, 120 dB vs. 1 kHz, 110 dB sound (formula collection, isophone curves) ?
135 Which one is louder: 30 Hz, 90 dB vs. 1 kHz, 70 phon sound (formula collection, isophone curves) ?
136 How much louder is a 80 dB versus a 70 dB sound at 1000 Hz?
137 Does a greater dB value always correspond to a louder sound?
138 Does a greater phon value always correspond to a louder sound?
139 Does a greater sone value always correspond to a louder sound?
140 Definition and interpretation of the audiogram.
141 Define hearing loss and overhearing.
142 Describe a pulse signal.
143 The monostable multivibrator and its applications.
144 The bistable multivibrator and its applications.
145 The astable multivibrator and its applications.
146 Special functions of a pacemaker.
147 Parameters of a pacemaker pulse: period, amplitude, duty ratio, energy.
148 Explain the ECG curve.
149 Compare the depolarization and repolarization processes of skeletal and cardiac muscles.
150 Types of ECG leads I.: bipolar leads.
151 Types of ECG leads II.: unipolar chest leads.
152 Types of ECG leads III.: (semi)unipolar limb leads.
153 Calculate the value of R(III) if R(I)= 0.2 mV and R(II)= 1 mV in the standard ECG leads.
154 Einthoven-triangle, integral vector.
155 Differential amplifier of ECG.
156 What is the voltage amplitude of a 12-mm-high R(I) signal if vertical sensitivity is 1 mV/cm?
157 What is the duration of a 2-mm-wide QRS complex if the horizontal scale is 25 mm/s?
158 Definition of x-ray density and its significance in CAT-scan.
159 Compare the x-ray absorption of bone and muscle tissue.
160 Compare the x-ray absorption of lung and muscle tissue.
161 What is the x-ray density of a voxel that absorbs 90% of the incident x-ray.
162 What is the advantage of using x-ray density (D) in computer tomography?
163 How do we resolve 3D structure in CT scanning?