Theory questions

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. Boltzmann distribution.
51. Applications of the Boltzmann-distribution I. : Nernst equation.
52. Applications of the Boltzmann-distribution II.: equilibrium and rate of chemical reactions. (The Arrhenius plot).
53. Applications of the Boltzmann-distribution III.: barometric formula.
54. Applications of the Boltzmann-distribution IV. electric conductivity of semiconductors.
55. Macrostate and microstate in thermodynamics.
56. Boltzmann’s definition of entropy.
57. Kinetic gas theory.
58. Maxwell-Boltzmann velocity distribution.
59. The Ideal gas.
60. The real gas.
61. State equation of real gases.
62. Pressure of ideal gases.
63. The crystalline state (unit cell, crystal defects).
64. Optical properties of crystalline materials.

65. Thermotropic liquid crystals.
66. Lyotropic liquid crystals.
67. Energy levels of electrical insulators.
68. The function of the semiconductor diode.
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 Beer-Lambert 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. Fluorescence.
93. Phosphorescence.
94. Luminescence spectra.
95. Stokes-shift.
96. The fluorescence spectrometer.
97. FRET.
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. Laser: population inversion.
106. Types of lasers.
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. Interaction of gamma radiation with matter II: Compton-scatter.
123. Interaction of gamma radiation with matter III: pair production.
124. Differential and integral forms of the decay law.
125. Interaction of beta negative radiation with matter.
126. Half-life and average lifetime of an isotope.
127. Interaction of beta positive radiation with matter.
128. Neutron radiation, proton radiation, the Bragg-peak.
129. Scintillation counter I.: the scintillation crystal.
130. Scintillation counter II.: the photomultiplier tube.
131. The gas ionization chamber.
132. Thermoluminescent dosimetry.

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. Principles of selecting the isotope for diagnostics according to radiation type and energy.
151. Parts and function of Tc-generator.
152. Cost-benefit principle in isotope diagnostics.
153. Definition of the radiopharmaceutical.
154. Determination of the biological half-life of an organ.
155. Relative depth dose.
156. Parts and function of gamma-camera.
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 filter circuits.
170. Digitalization of analog signals.
171. Shannon-Nyquist theorem.
172. Processing of pulse signals.
173. X-rays: Typical diagnostic wavelength and photon energy range.
174. Structure and function of the x-ray tube.
175. The Duane-Hunt-law.
176. Spectrum of Bremsstrahlung.
177. Production of characteristic x-rays.
178. Power and efficiency of the x-ray tube.
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. Brownian motion. Random walk.
198. Basics of diffusion: Concepts, thermal motion.
199. Fick's I. law.
200. Fick's II. law.

201. The diffusion coefficient. Einstein-Stokes-equation.
202. Thermodiffusion.
203. Heat transport, Fourier’s law.
204. Physical quantities used for describing the transport of matter.
205. Gas exchange between blood and alveoli.
206. Osmosis, osmotic pressure, osmolarity.
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. Fundamentals of thermodynamics III.: types of energies, internal energy and its components.
210. The 1st law of thermodynamics and its applications for biological systems.
211. The 2nd law of thermodynamics, direction of spontaneous processes.
212. The 3rd law of thermodynamics.
213. Extensive and intensive quantities and their relations.
214. Entropy and its connections with order, thermal and configurational entropy.
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, 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. Phase diagram of water.
243. Anomalous behavior of water.
244. Structure of biopolymers.
245. Structural hierarchy of proteins.
246. Protein-stabilizing interactions.
247. Protein folding.
248. Biopolymer elasticity.
249. Structure and elasticity of DNA.
250. Steps of sensory signal transduction.
251. Information coding by the receptor potential.
252. Information coding by the action potential.
253. Sensory adaptation.
254. Stevens' Law.
255. Weber-Fechner law.
256. Biophysics of hearing I.: the outer ear.
257. Biophysics of hearing II.: the middle ear.
258. Biophysics of hearing III.: Békésy's hearing model.
259. Biophysics of hearing IV.: signal transduction in hair cells.
260. Signal amplification by hair cells.
261. The phon scale.
262. The sone scale.

263. Reaction steps of light sensation.
264. Photoreceptors of the retina.
265. Basis of color sensing.
266. Biomechanics I.: Stress-strain diagram and its ranges.
267. Biomechanics II.: Hooke's law, Young-modulus.
268. Biomechanics III.: Laplace-Frank-equation.
269. Viscoelasticity I.: mechanical model
270. Viscoelasticity II.: stress-relaxation, energy dissipation.
271. Biomechanical characteristics of bone and enamel.
272. Biomechanics of elastic arteries, distensibility.
273. Structure and types of motor proteins.
274. Processivity, typical force range and working distance of motor proteins.
275. Muscle biophysics I.: twitch, summation, tetanus.
276. Muscle biophysics II.: isometric and isotonic contraction.
277. Muscle biophysics III.: work and power. Force-velocity curve.
278. Bragg-diffraction of X-rays.
279. The sliding filament model of muscle contraction.
280. The cross-bridge cycle of skeletal muscle myosin.
281. Determination of molecular structure by x-ray crystallography.
282. Ionization methods in mass spectrometry: electrospray, MALDI.
283. Time of flight principle in mass spectrometry.
284. Mass spectrometry in medicine: proteomics, diagnostics, oncoknife.
285. Stern-Gerlach-experiment.
286. Zeeman-effect.
287. Differences between NMR and ESR spectroscopies.
288. Chemical shift.
289. Larmor-precession and nuclear magnetic resonance.
290. Macroscopic magnetization in MRI: spin-spin relaxation.
291. Macroscopic magnetization in MRI: spin-lattice relaxation.
292. Spatial encoding in MRI.
293. MRI contrast methods: proton density, T1 and T2 weighting.
294. Circulatory biophysics: function of the blood vessel system.
295. Pressure relations in the arterial system.
296. Changes in pressure in the circulatory system.
297. Auxiliary factors of circulation: the windkessel effect.
298. Changes in the total cross section of vessels in the circulatory system.
299. Pressure-volume relation of the heart.
300. Electrical description of heart function.
301. The cardiac cycle.
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. Respiratory volumes and capacities.
307. Conductive and gas-exchange parts of the human respiratory sytem.
308. Biomechanics of respiration. (compliance, obstructive and restrictive pathologies)
309. Respiratory work.
310. Biophysics of physical examination I.: Inspection.
311. Biophysics of physical examination II.: palpation.
312. Biophysics of physical examination III.: Percussion
313. Box model of the human respiratory system.
314. Biophysics of physical examination IV.: Auscultation.

Practice questions

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 vision 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 is 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 is diffusion 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 (thereshold of hearing, threshold of pain, frequency limits).
134. Which one is louder: 50 Hz, 120 dB vs. 1 kHz, 110 dB (formula collection, isophone curves)
135. Which one is louder: 30 Hz, 90 dB vs. 1 kHz, 70 phon (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.: 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?