Medical biophysics final exam topic list 2025

I. Theory topics

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. Optical image formation on a curved surface.
11. Principal light rays.
12. Lens combinations.
13. Refractive power.
14. Lens equation.
15. Image formation by the compound 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, Rutherford).
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 thermo-optical 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. Properties of 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. Properties of 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 I: 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.
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, the 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. 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 remarkable ranges.
267. Biomechanics IV.: Laplace-Frank-equation.
268. Viscoelasticity I.: mechanical model
269. Biomechanics II.: Hooke's law, Young's 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 system.
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.
315. Explain the ECG curve.
316. Einthoven-triangle, integral vector.
317. Types of ECG leads I.: bipolar leads.
318. Types of ECG leads II.: unipolar chest leads.
319. Types of ECG leads III.: (semi)unipolar limb leads.
320. Role of differential amplifier in the ECG equipment.