EM semifinal questions 2021-2022 I. Semester

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. Image formation on a curved surface.
11. Principal light rays of the optical lens.
12. Lens combinations.
13. Refractive power.
14. Lens equation.
15. Image formation by the light microscope.
16. Image formation by converging lens.
17. 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 in 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 (AFM).
50. The Ideal gas.
51. Maxwell 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 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. 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. Förster's Resonance Energy Transfer (FRET).
96. Phosphorescence.
97. Stokes-shift.
98. Fluorescence Recovery After Photobleaching (FRAP).
99. 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. Definition and types 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 dosimeter.
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: half-life.
150. Parts and function of Tc-generator.
151. Cost-benefit principle in isotope diagnostics.
152. Principles of selecting the isotope for diagnostics: 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 isotope.
156. Relative depth dose.
157. Scintigraphy.
158. Single Photon Emission Computer Tomography (SPECT).
159. Teletherapy, geometric considerations.
160. Interpretation of a typical isotope accumulation curve.
161. Parts and working principle of the positron emmission tomograph (PET).
162. Role of collimators in radiation therapy; the gamma-knife.
163. -
164. Principles of brachytherapy.
165. Classification and comparison of signals.
166. Typical frequency and amplitude ranges of biological signals.
167. Positive and negative feedback amplifiers.
168. Fourier-theorem for periodic and aperiodic signals.
169. Parts and function of high- and low-pass filter circuits.
170. Digitization of analog signals.
171. Shannon-Nyquist theorem.
172. Processing of pulse signals.

II. Lab topics

1. How does the refractive power of a lens change if its radius of curvature decreases?
2. How does the refractive power of a lens change if its radius of curvature increases?
3. What is the radius of curvature in case of a lens?
4. How does the 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 types of samples can be measured with the Abbe-refractometer?
16. What is the role of the Amici prism?
17. What is optical dispersion?
18. Factors influencing the value of index of refraction.
19. Formation of Snell's window.
20. How do you determine concentration by refractometry?
21. -
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 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's 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 is decreased?
39. How does optical rotation angle change if the sample is concentration increased?
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 by the eye.
44. What is the refractive power of the unaccommodated human eye?
45. Which refractive surface contributes the most to the refractive power of the human eye?
46. How does the refractive power of the human eye change during accommodation?
47. Describe the process of focal accommodation of the human eye.
48. How do you calculate the accommodation 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 visual acuity?
55. Describe the reduced eye model.
56. Factors influencing 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 can external noise be reduced in scintillation counting?
62. How can internal noise be reduced in scintillation counting?
63. Describe the function of the integral discriminator.
64. Define the signal-to-noise ratio.
65. How do you find the optimal integral discriminator 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. Why?
67. Define the mass attenuation coefficient.
68. Define 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.
73. Compare the linear and mass attenuation coefficients of liquid 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. Gain and gain level of the amplifier.
85. Compare voltage gain and power gain.
86. What is the gain level if the voltage gain is 1000?
87. What is the gain level if the voltage gain is 1?
88. What is the power gain if the gain level is 3 dB?
89. Frequency response curve of the amplifier.
90. How do you determine the transfer band of an amplifier.
91. How does the bandwidth of an amplifier change with negative feedback.
92. Advantages and disadvantages of using negative feedback in an amplifier.
93. Voltage divider circuit.

III. Calculations

*(The exam calculations will be **similar** to the ones listed below.)*

- Miklós Kellermayer: Medical Biophysics Practices, from Chapter: 31.PROBLEMS:
  1. / 2. / 6. / 9. / 13. / 19. / 25. / 26. / 32. / 34. / 36. / 44. / 45.

- From the pdf files at http://biofiz.semmelweis.hu/, under the Homework problems tab in Medical Biophysics I.:
  2.10. / 2.11. / 2.12.a / 2.13. / 2.14. / 2.23.a / 2.23.b / 2.28.a / 2.77.c 2.78.e / 2.151.a / 2.151.c / 4.4. / 4.8.a / 4.9.a / 4.9.b / 11.1. / 11.2. 11.3. / 11.6.b / 11.7.b / 11.10.a / 11.10.b / 11.12.a / 11.12.b / 12.1.a 12.1.c/ X1. / X2. /X3. / X4.

IV. Excel tasks

You have to know the tasks that you have been doing during Biophysics Labs in excel. These include data processing, graphical representation of data and calculations. ***Sample task will be uploaded by the end of November.***