Medical Equipment I Term Exam – January 2011 (Model Answer)

Solve as Much as You Can – Maximum Grade: 70 Points

Part I. Answer these questions by marking the best answer among the choices given (1 point each):

1. The lowest energy required to remove an electron from a ground state atom is called …
   a. Energy level
   b. Auger
   c. Ionization energy (*)
2. Radiation beam attenuation mechanisms do not include …
   a. Absorption
   b. Scattering
   c. Refraction (*)
3. One can compute the number of photons after passing through a substance using …
   a. Beer's law (*)
   b. Snell's law
   c. Pauli's principle
4. In an atomic gas, the ratio of excited atoms to those in ground state is estimated using …
   a. Stefan-Boltzmann law
   b. Planck's formula
   c. Boltzmann ratio (*)
5. Theoretical calculation of total power of Blackbody radiation can be done by integrating … over all wavelengths.
   a. Stefan-Boltzmann law
   b. Boltzmann ratio
   c. Planck's formula (*)
6. Photon energy depends on …
   a. Speed of propagation
   b. Light polarization
   c. Wavelength (*)
7. The action spectrum at wavelength of 290 nm is equal to …
   a. 0.01
   b. 0.1
   c. 1 (*)
8. Erythema can be the result of … UV exposure.
   a. Acute (*)
   b. Long-term
   c. Chronic
9. Interaction total cross section from multiple mechanisms such as photoelectric effect and Compton scattering is …
   a. The sum of all individual cross sections. (*)
   b. The vector sum of all cross sections.
   c. The mean of all cross section.
10. Energy fluence rate from a Lambertian surface is …
    a. Source-independent
    b. Direction-independent (*)
    c. Wavelength-independent
11. Pauli exclusion principle states that …
    a. The interactions that take place in one atom may not occur at the same time.
    b. No two electrons in an atom can have the same values for all their quantum numbers. (*)
    c. Photon interactions are mutually exclusive.
12. Interaction cross section defines …
    a. The area in front of the main beam
    b. The area in front of the broad beam including scattering
    c. The probability of that particular interaction taking place (*)

13. Light speed in materials does not depend on …
    a. Opacity of material (*)
    b. Color of light
    c. Composition of material
14. As light moves from one medium into another, its … changes.
    a. Frequency
    b. Wavelength (*)
    c. Spectrum
15. The K-edge in the photoelectric cross section results from …
    a. Critical energy to remove L electron is achieved
    b. K electrons cross section term removed from total cross section (*)
    c. Compton scattering beginning to be dominant at this energy
16. Radiant intensity is used to describe …
    a. Point source (*)
    b. Extended source
    c. Plane wave source
17. In pair production, momentum is conserved by taking … into account.
    a. Recoil of nucleus (*)
    b. Recoil of electron
    c. Recoil of positron
18. Below 1.04 MeV, … cannot occur.
    a. incoherent scattering
    b. Coherent scattering
    c. pair production (*)
19. When a photon with energy $h\nu$ strikes an atom resulting in the emission of a photoelectron from the K shell, the total energy of the system after this interaction is …
    a. $h\nu$ (*)
    b. B_K
    c. $h\nu$-B_K
20. For an atom with a hole in its K shell, when a non-radiative transition occurs an electron with energy … is emitted.
    a. B_K- B_L
    b. B_K-$2B_L$ (*)
    c. $h\nu$
21. During the deexcitation of an atom with a hole in the K shell, if one Auger electron from the L shell and two L Fluorescence photons were emitted, then the final excitation energy of that atom will be …
    a. B_K-B_L
    b. B_L
    c. 0 (*)
22. Electron energy can be converted to photons using a process called …
    a. Coster-kronig transition
    b. Bremsstrahlung (*)
    c. Auger cascade
23. The K-edge jump in photoelectric cross section amounts to …
    a. τ_K (*)
    b. τ_L
    c. τ_K-τ_L
24. The photoelectric cross section of a material is … that of another with half its atomic number around 100 keV.
    a. Double
    b. 4 times
    c. 16 times (*)
25. In Compton scattering, we derive the angles and energies of the scattered electron and photon by solving …
    a. Conservation of energy and momentum in 2 directions (*)
    b. Special relativity
    c. Klein–Nishina Formula
26. The special relativity relates the energy of a moving electron to its …
    a. Kinetic energy and potential energy
    b. Momentum and mass (*)
    c. Mass and speed of light

27. The difference between Compton and incoherent scattering is that …
    a. Compton scattering involves only one atom
    b. Compton scattering involves more than one electron
    c. Incoherent scattering involves all electrons in the atom (*)
28. The spherical aberration in the eye is characterized by …
    a. Variation of index of refraction of the lens with wavelength
    b. Variation of index of refraction of the lens with distance from the axis of the eye (*)
    c. Lack of accommodation from aging
29. In hyperthermia, the target spot is heated as a result of …
    a. Absorption of incident photons (*)
    b. Blood perfusion
    c. Heat diffusion
30. If the K-shell photoelectric cross section for 100-keV photons on lead (Z = 82) is $\tau = 1.76 \times 10^{-25}$ m^2/atom, then the photoelectric cross section for 60-keV photons will be …
    a. 3.8×10^{-26} m^2/atom
    b. 8.15×10^{-25} m^2/atom (*)
    c. 1.06×10^{-25} m^2/atom
31. If a 1-MeV photon undergoes Compton scattering with scattered photon having an energy of 500keV, then the scattering angle of the photon will be approximately …
    a. 30°
    b. 60° (*)
    c. 90°
32. A beam of 59.5-keV photons from ^{241}Am scatters at 90° from some carbon atoms (A = 12). The energy of a coherently scattered photon in this case will be …
    a. 34.6 keV
    b. 53.1 keV
    c. 59.5 keV (*)
33. For incoherent scattering of an incident photon of energy E, the maximum energy of the emerging photon will be …
    a. E (*)
    b. E/2
    c. $m_e c^2$
34. Assuming the absorption coefficient of a human tissue is 5 m^{-1} and that this tissue has the density of water and a molecular weight of 18, the absorption cross section will be equal to …
    a. 15×10^{-29} m^2/particle (*)
    b. 20×10^{-29} m^2/particle
    c. 30×10^{-29} m^2/particle
35. If a relaxed eye focuses at a distance of 200 cm, the strength of the desired corrective lens should be … diopters.
    a. -0.5 (*)
    b. -1
    c. -2
36. Edema can occur when there is …
    a. an increase in osmotic pressure inside capillaries
    b. an increase in osmotic pressure in extracellular space (*)
    c. an increase in level of medium-weight molecule inside blood
37. In artificial kidney using cellophane membrane dialyzer, if ωRT is 5×10^{-6} m/s, surface area of dialyzer is 3 m^2, and body fluid volume is 40 liters, the time constant for the diffusion process in the treatment is approximately …
    a. 2.2 hours
    b. 1.1 hours
    c. 45 minutes (*)
38. Osmotic pressure is associated with … membranes.
    a. semipermeable (*)
    b. permeable
    c. permeable and semipermeable
39. Solvent drag means …
    a. Solute particles drifting with solvent (*)
    b. Solvent attracting solute molecules by diffusion
    c. Newtonian flow of solvent

40. Fick's second law of diffusion combines …
    a. Fick's first law of diffusion and the continuity equation (*)
    b. Fick's first law of diffusion and Einstein relationship
    c. Einstein relationship and the conservation of mass
41. Entropy of a system is maximum at …
    a. Low temperatures
    b. High temperatures
    c. Equilibrium (*)
42. Consider the combined decay of two processes with decay constants 1 and 2 s^{-1} respectively. Then, the half-life time as a result of both processes is given by …
    a. 0.693 s
    b. 0.231 s (*)
    c. 0.347
43. The plot of the function $f(x)= x^{0.2}$ appears … on a log-log plot
    a. Linear (*)
    b. piecewise linear
    c. nonlinear
44. The plot of the function $f(x)= 5\ e^{3x}$ has an intercept of … on a semi-log plot.
    a. 0
    b. 1
    c. 5 (*)
45. To reach double the diffusion distance, the diffusion time required must be multiplied by …
    a. ½
    b. 2
    c. 4 (*)
46. Heavier particles in Brownian motion move … lighter particles of the same size.
    a. Faster than
    b. Slower than (*)
    c. As fast as
47. Fick's first law of diffusion is derived from …
    a. empirical observations (*)
    b. conservation of mass
    c. conservation of energy
48. In a disease that causes an increase in both the arterial and venous pressures by 10 mmHg combined with an increase in blood proteins leading to a +10 mmHg osmotic pressure increase results in …
    a. No change in tissue water content (*)
    b. Edema
    c. Loss of body fluids
49. A particular disease in an animal is linked to a defective X chromosome and appears only when all X chromosomes present are defective. If the probability of a single X chromosome to be defective is 0.01, The percentage of population carrying this disease if each animal has 2 X chromosomes is …
    a. 0.0001 (*)
    b. 0.00001
    c. 0.000001
50. Sterilization systems belong to …
    a. Physical environment (*)
    b. Clinical environment
    c. Both of the above
51. Based on Balanced Noise Criterion Curves, for NCB value of 25, the sound pressure level at 500 Hz should be …
    a. 20 dB
    b. 30 dB (*)
    c. 40 dB
52. Maximum temperature for equipment parts likely to be touched should never exceed …
    a. 86° (*)
    b. 80°
    c. 60°

53. To accommodate medical device users' needs and preferences, …
    a. rely exclusively on thought leaders to put the product specifications
    b. plan a comprehensive training for users
    c. let users set the pace while working with the medical device (*)
54. Anesthesia machines use … to ensure that users turn the correct knob to increase the flow of O_2 vs. air or N_2O.
    a. Visible alarm
    b. Redundant coding (*)
    c. Error messages
55. Undesirable or unexpected events resulting from the interaction between a user and a device is called …
    a. Slip
    b. Lapse
    c. User error (*)
56. To prioritize different types of hazards in a medical device, … is used.
    a. Risk equation (*)
    b. FTA
    c. FMEA
57. Fault tree analysis (FTA) differs from failure mode effects analysis (FMEA) is that …
    a. FMEA involves brainstorming that is not required in FTA
    b. FMEA works from the bottom up, while FTA starts from top-level hazards down. (*)
    c. FTA is more suitable for clinical environment whereas FMEA is best for industrial settings.
58. For a visual angle of 18 min of arc, the font of a sign to be readable from 3 m away should be at least …
    a. 24
    b. 36
    c. 45 (*)
59. According to the fatigue curve, a user exerting 30% of his maximum muscle strength can continue for … minutes before fatigue.
    a. 5 minutes
    b. 2.5 minutes (*)
    c. 1 minute
60. Identification of both individual elements and their functional relationships in the medical device user interface can be best done through …
    a. Appropriate markings and labeling (*)
    b. Design changes
    c. Using FMEA

Part II. Mark the following statement as either True (T) or False (F) (½ point each):

61. The radiation energy from a heated atom changes when it is in atomic gas or solid form. (T)
62. A system that has adiabatic walls does not exchange heat with surroundings (T)
63. Entropy change is related to mechanical work (F)
64. Exponential growth can be plotted as a linear curve using log-log plots (F)
65. Work is calculated as the area under the pressure-volume curve (T)
66. Isolation of an infectious compartment can be done using semipermeable membranes (F)
67. A process in which the change in quantity Q with time is proportional to Q is a semilog process (F)
68. The rate of increase of a quantity in an exponential growth process is proportional to that quantity. (T)
69. It is possible to use classical mechanics to describe systems of many particles when needed. (F)
70. Functions with variable exponential decay rate cannot be analyzed using semi-log plots (F)
71. Diffusion happens as a result of Brownian motion of particles in a fluid. (T)
72. When the probability of all available microstates is the same, the system is at equilibrium. (T)
73. The entropy of a system is equal to the root mean square of entropies of its subsystems. (T)
74. Diffusion is the main mechanism for oxygen transport to capillaries through alveoli. (T)
75. Minimum energy for pair production to occur is 0.51 MeV. (F)

76. In broad-beam geometry, scattered photons may still reach the detector. (T)
77. The advantage of mass attenuation coefficient is that it varies only with Z/A. (F)
78. Fluorescence and Auger deexcitation mechanisms are two competing processes. (T)
79. Fluorescence yield increases with atomic number. (T)
80. Peak of coherent scattering cross section is narrower for elements of lower atomic number. (T)
81. The cross section of coherent scattering is always peaked in the backscattering direction. (F)
82. Auger cascade is important because of its molecular bond-breaking effect. (T)
83. Photometry is the process of measuring photon flux. (F)
84. Light speed in some material can be more than that of vacuum. (F)
85. Emission or absorption of energy by single atoms is possible only at specific wavelengths. (T)
86. Sodium is easier to ionize than Hydrogen. (T)
87. Interaction cross section is related to linear attenuation coefficient. (T)
88. Blood oximetry is done using measurement of light attenuation in blood at the isosbestic point. (F)
89. Resolution in the micron range can be obtained with optical coherence tomography. (T)
90. Emissivity of a blackbody changes only with wavelength. (F)
91. Human skin of any color behaves closely like an ideal blackbody near IR. (T)
92. Having a glass window in an incubator room is not allowed to prevent UV radiation overexposure. (F)
93. Photons of UV light treat neonatal jaundice by breaking down bilirubin molecules into more soluble forms. (T)
94. The cross section of the photoelectric effect depends on photon energy. (T)
95. Raman scattering of IR light involves scattered photons that do not have same original energy as the incident. (T)
96. Designers must not anticipate medical device migration into other uses or use environments. (F)
97. Designers should diverge substantially from conventional design practice or industry standards. (F)
98. Users regard action confirmation messages as a wasted extra step and therefore should be avoided. (F)
99. Medical devices designed with multiple operational modes must clarify the present operating mode to the user. (T)
100. When possible, medical monitoring device designs should help users forecast patient variables. (T)
101. Validation must be done by clinicians whereas verification is mainly done by design engineers. (T)
102. After implementing design change to mitigate a risk, new risks may arise as a result of this change. (T)
103. An audible alarm can be designed as a pure tone with frequency of 100Hz and intensity level of 20 dB. (F)
104. An old man is more likely to hear a high frequency tone than a low frequency tone. (F)
105. Device user interface designs usually violate at least one human factors engineering guideline. (T)
106. Medical device users always receive complete and proper training before using a given device. (F)
107. Designers should treat warnings as the main option for preventing problems in medical devices. (F)
108. Reaction time for auditory alarms is usually faster than that for visible alarms. (T)
109. Medical devices may increase relative humidity in the environment to be 45% at 21ºC. (T)
110. Anthropometric information in the public domain is available for all applications. (F)
111. Location aids can be used to indicate functional relationships. (T)
112. Medical device package labels include only shipping and storage requirements. (F)
113. Humans tend to overestimate the weight of an object if it is bulky in size. (T)
114. Horizontal hand movements are faster than vertical. (T)
115. It is necessary to mitigate abnormal use by a user who actually intends to use a device incorrectly. (F)
116. Usability test participants should include someone from the design team in addition to doctors and nurses. (F)
117. Intended use of a medical device includes clinical application and use environment. (F)
118. Mistakes arise from applying the wrong knowledge when making a decision. (T)
119. Chemical sense can be used reliably in some medical devices. (F)
120. Channel capacity is similar among the sensory modalities. (T)

Best of Luck!