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. Theoretical calculation of total power of Blackbody radiation over all wavelengths is called …
   a. Stefan-Boltzmann law (*)
   b. Boltzmann ratio
   c. Planck's formula
2. The energy of a photon changes with its …
   a. Speed of propagation
   b. Light polarization
   c. Frequency (*)
3. Premature aging of the skin can be the result of … UV exposure.
   a. Acute
   b. Intense
   c. Chronic (*)
4. Interaction total cross section when both photoelectric effect and incoherent scattering occur is …
   a. The sum of individual cross sections (*)
   b. The root mean square of individual cross sections
   c. The mean of individual cross sections
5. No two electrons in an atom can have the same values for all their quantum numbers according to …
   a. General relativity
   b. Special relativity
   c. Pauli's exclusion principle (*)
6. Interaction cross section defines …
   a. The probability that an area is in front of the main beam
   b. The area of inside the beam that is capable of interacting with matter
   c. The probability of a particular interaction taking place (*)
7. Light speed in materials depends on …
   a. Opacity of material
   b. Color of light (*)
   c. Frequency change inside the material
8. The jump magnitude of the K-edge in the photoelectric cross section is equal to …
   a. Critical energy to remove K electron
   b. K electrons cross section (*)
   c. L electrons cross section
9. Radiance is used to describe …
   a. Point source
   b. Extended source (*)
   c. Plane wave source
10. In pair production, momentum is conserved by taking … into account.
    a. Recoil of nucleus (*)
    b. Recoil of electron
    c. Recoil of positron
11. Below 2 MeV, … does not have appreciable cross section.
    a. incoherent scattering
    b. Coherent scattering
    c. pair production (*)
12. When a photon with energy hν strikes an atom resulting in the emission of a photoelectron from the K shell which is then followed by the emission of an L Auger electron, the total energy of the system after this series of interactions is …

a. $h\nu$ (*)
b. B_K
c. $h\nu - B_K$

13. For an atom with a hole in its K shell, when a radiative transition occurs, a photon with energy … is emitted.
    a. $B_K - B_L$ (*)
    b. $B_K - 2B_L$
    c. $h\nu$
14. 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 (*)
15. Photon energy can be transferred to electrons using a process called …
    a. Coster-kronig transition
    b. Photoelectric effect (*)
    c. Coherent scattering
16. The L-edge jump in photoelectric cross section amounts to …
    a. τ_K
    b. τ_L (*)
    c. $\tau_K - \tau_L$
17. The photoelectric cross section for a 100keV photon beam is … times that of another with double its energy.
    a. 1/8
    b. 8 (*)
    c. 16
18. 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
19. The special relativity relates the energy of a moving electron to its …
    a. Kinetic energy and potential energy
    b. Mass
    c. Mass and momentum (*)
20. 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 (*)
21. 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
22. In hyperthermia, the target spot is heated as a result of …
    a. Absorption of incident photons (*)
    b. Blood perfusion
    c. Heat diffusion
23. 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
24. 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°
25. 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 (*)

26. 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. $m_e c^2$
27. 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 x 10^{-29} m^2/particle (*)
    b. 20 x 10^{-29} m^2/particle
    c. 30 x 10^{-29} m^2/particle
28. 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
29. In artificial kidney using cellophane membrane dialyzer, if ωRT is 5×10^{-6} m/s, surface area of dialyzer is 1 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
30. Osmotic pressure is encountered with … membranes.
    a. semipermeable (*)
    b. permeable
    c. all
31. Solvent drag means …
    a. Solute particles drifting with solvent (*)
    b. Solvent attracting solute molecules by diffusion
    c. Newtonian flow of solvent
32. 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
33. Entropy of a system is maximum at …
    a. Low temperatures
    b. High temperatures
    c. Equilibrium (*)
34. 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
35. The plot of the function $f(x)= x^{0.2}$ appears … on a log-log plot
    a. Linear (*)
    b. piecewise linear
    c. nonlinear
36. 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 (*)
37. To reach 3 times the diffusion distance, the diffusion time required must be multiplied by …
    a. ½ (*)
    b. 2 (*)
    c. 4 (*)

All answers (including no answer) will be counted as correct answer

38. Heavier particles in Brownian motion have energies that are … lighter particles of the same size.
    a. higher than
    b. lower than
    c. same as (*)
39. Fick's second law of diffusion is derived from …

a. Fick's first law and continuity equation (*)
b. conservation of mass and Brownian motion
c. conservation of energy and Fick's first law

40. In a disease that causes an increase in both the 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 (*) Same answer (value of (arterial pressure-osmotic) will be lower than normal)
41. The lowest energy required to remove an electron from a ground state atom is called …
    a. Energy level
    b. Auger
    c. Ionization energy (*)
42. Radiation beam attenuation mechanisms include …
    a. penetration
    b. Scattering (*)
    c. Refraction
43. In an atomic gas, the ratio of excited atoms to those in ground state can be estimated using …
    a. Stefan-Boltzmann law
    b. Planck's formula
    c. Boltzmann ratio (*)
44. 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 three X chromosomes is …
    a. 0.0001
    b. 0.00001
    c. 0.000001 (*)
45. 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 (*)
46. 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
47. Undesirable or unexpected events resulting from the interaction between a user and a device is called …
    a. Slip
    b. Lapse
    c. User error (*)
48. To prioritize different types of hazards in a medical device, … is used.
    a. Risk equation (*)
    b. FTA
    c. FMEA
49. 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.
50. 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 (*)

Part 2: Mark the following statement as either True (T) or False (F) (½ point each):

51. The radiation energy from a heated atom does not change regardless if it is in atomic gas or solid form. (F)
52. Diffusion is the main mechanism for oxygen transport from the outside air to the alveoli. (F)

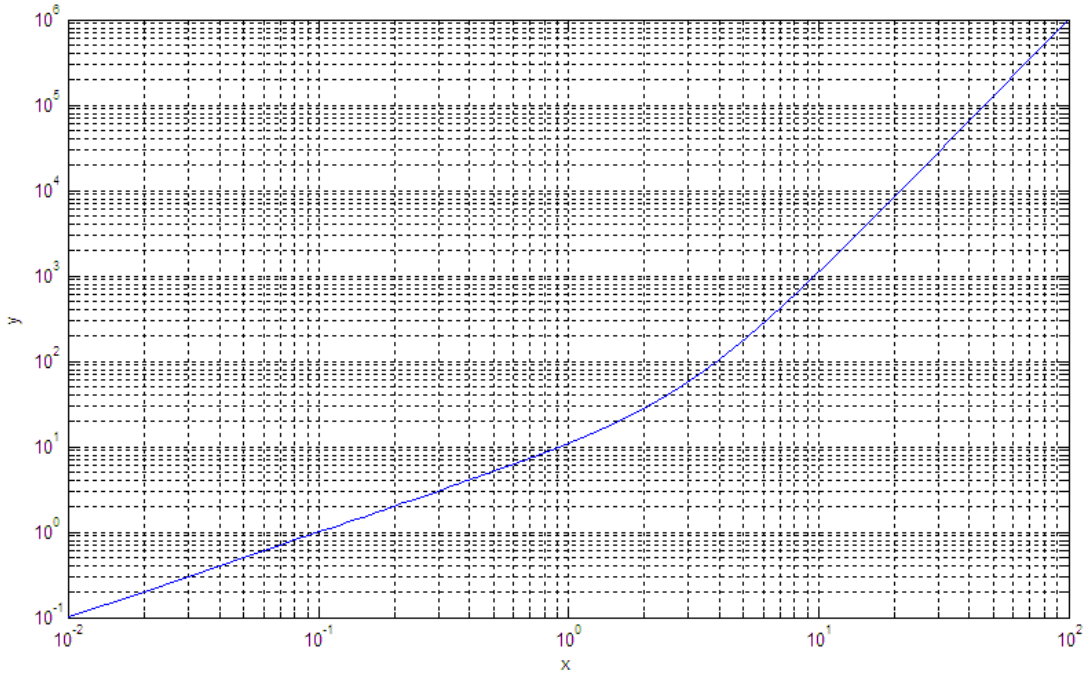
53. In narrow-beam geometry, scattered photons are unlikely to reach the detector. (T) Same answer is correct
54. The advantage of mass attenuation coefficient is that it is independent of density. (T)
55. Fluorescence and Auger deexcitation mechanisms are two competing processes. (T)
56. Fluorescence yield decreases with atomic number. (F)
57. The cross section of coherent scattering is always peaked in the forward direction. (T)
58. Auger cascade is important because of its molecular bond-breaking effect. (T)
59. Photometry is the process of measuring photon flux. (F)
60. Light speed in materials with refraction index less than one can be higher than that of vacuum. (F) Same answer
61. Peak of coherent scattering cross section is narrower for elements of higher atomic numbers. (F)
62. Emission or absorption of energy by single atoms is possible only at a few specific energy values. (T) same answer
63. Hydrogen is easier to ionize than Sodium. ~~(T)~~ (F)
64. Interaction cross section is related to linear attenuation coefficient. (T)
65. Blood oximetry is done using measurement of light attenuation in blood at the isosbestic point. (F)
66. Emissivity of a blackbody changes only with wavelength. (F)
67. A system that has adiabatic walls does not exchange heat with surroundings (T)
68. Entropy change is related to heat exchange (T)
69. Isolation of an infectious compartment can be done using isolation systems based on laminar flow. (T)
70. It is difficult to use classical mechanics to describe systems of many particles. (T)
71. Functions of exponential growth form cannot be analyzed using semi-log plots (F)
72. Diffusion results in Brownian motion of particles in a fluid. (F) "results in" means "causes ", which is not true
73. Photons of UV light treat neonatal jaundice by breaking down bilirubin molecules into more soluble forms. (T)
74. The cross section of the photoelectric effect depends on photon wavelength. (T) same answer
75. Raman scattering of IR light involves scattered photons that do not have same original energy as the incident. (T)
76. Designers should anticipate medical device migration into other uses or use environments. (T)
77. Designers should never diverge substantially from conventional design practice or industry standards. (T) same answer
78. Users regard action confirmation messages as a wasted extra step and therefore should be avoided. (F)
79. Medical devices designed with multiple operational modes must clarify the present operating mode to the user. (T)
80. When possible, medical monitoring device designs should help users adjust patient vital signs. (F) same answer
81. Validation must be done by clinicians whereas verification is mainly done by design engineers. (T)
82. After implementing design change to mitigate a risk, the design is ready for marketing and patient use. (F)
83. Device user interface designs must not violate any human factors engineering guideline. (F) same answer
84. Medical device users may not always receive complete and proper training before using a given device. (T)
85. Designers should treat warning labels as the last option for preventing problems in medical devices. (T)
86. Reaction time for auditory alarms is usually faster than that for visible alarms. (T)
87. It is not necessary to mitigate abnormal use by a user who actually intends to use a device incorrectly. (T) same answer
88. Usability test participants should not include anyone from the design team. (T)
89. Intended use of a medical device includes clinical application and use environment. (F) same answer
90. Mistakes arise from applying the right knowledge when error occurs. (F)

Part 3 [5 points]: Consider the processes in the table below involving the photoelectric interaction of a photon of energy hν and an atom in ground state and the subsequent deexcitation events. It is required that you fill out the table values to accurately reflect the energies at the time points indicated.

Process	Total photon energy	Total electron energy	Atom excitation energy	Sum
Before photon strikes atom	hν	0	0	hν
After photoelectric effect with emission of K electron	0	$h\nu - B_K$	B_K	hν
After L electron fills hole in K Shell and emission of Auger electron from M Shell	0	$h\nu - B_K$, $B_K-B_L-B_M$	B_L+B_M	hν
After emission of M fluorescence photon	B_M	$h\nu - B_K$, $B_K-B_L-B_M$	B_L	hν

Just follow the same steps as the Deexcitation table in Chapter 15.

Part 4 [5 points]: Derive the equation of the curve shown below.



Y(x)= 10 x + x^3 – compute the slow components first then subtract it and obtain the fast like in Chapter 2 problems.

Best of Luck!