Biomedical Engineering Department
Cairo University

Time Allowed: One Hour
Open-Book/Open-Notes

Medical Equipment II Mid-Term Exam – April 2010

Solve as Much as You Can – Maximum Grade: 100 Points

Part I. Answer the following questions by marking the best answer among the choices given (3 points each):

1. Light speed in materials depends on …
    a. Color of light
    b. Composition of material
    c. Both of the above (*)
2. As light moves from one medium into another, … remains the same
    a. Frequency (*)
    b. Wavelength
    c. Speed of propagation
3. Photon energy depends on …
    a. Speed of propagation
    b. Frequency (*)
    c. Light polarization
4. Photons of the visible spectrum have energies in the range of …
    a. Few keVs
    b. Few eVs (*)
    c. Few meV (milli-eV)
5. The smallest amount of energy required to remove an electron from a ground state atom is called …
    a. Energy level
    b. Quantum energy
    c. Ionization energy (*)
6. Radiation beam attenuation means …
    a. Absorption of photons
    b. Scattering of photons
    c. Both of the above (*)
7. The formula that computes the number of photons after passing through a substance is called …
    a. Beer's law (*)
    b. Snell's law
    c. Pauli's principle
8. The technology behind optical coherence tomography relies on …
    a. Interferometry (*)
    b. Echo ranging methods (like ultrasound imaging)
    c. High coherence light source
9. In atomic gas form, the ratio of excited sodium atoms to those in ground state is estimated using …
    a. Stefan-Boltzmann law
    b. Boltzmann ratio (*)
    c. Planck's formula

10. 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 (*)
11. The erythema action spectrum at wavelength of 290 nm is equal to …
    a. 1 (*)
    b. 0.1
    c. 0.01
12. Skin cancer can be the … result of UV exposure.
    a. Acute
    b. Short-term
    c. Chronic (*)
13. Te problem of relying only on sun protection factor to choose a sun screen is that …
    a. It describes protection from UVA only
    b. It describes protection from UVB only (*)
    c. It describes protection from UVC only
14. 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.
15. Energy fluence rate from a Lambertian surface is …
    a. Source-independent
    b. Direction-independent (*)
    c. Wavelength-independent
16. 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.
17. 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 (*)
18. The K-edge in the photoelectric cross section results from …
    a. K electron cross section term removed from total photoelectric cross section equation (*)
    b. Critical energy to remove L electron is achieved
    c. Compton scattering beginning to be dominant at this energy
19. If most diagnostic x-rays use photon energies in the range 20–100 keV, the dominant interaction in this range is …
    a. Photoelectric effect (*)
    b. Compton scattering
    c. Coherent scattering
20. Radiance is used to describe …
    a. Point source
    b. Extended source (*)
    c. Plane wave source

Part II. Mark the following statement as either True (T) or False (F) (1.5 point each):

21. Light speed in some material can be more than that of vacuum. (F)
22. Emission or absorption of energy by single atoms is possible only at specific wavelengths. (T)
23. Two electrons in an atom can have the same values for 5 of their quantum numbers. (F)
24. Sodium is more difficult to ionize than Hydrogen. (F)
25. Blue color of sky is due to light absorption in the atmosphere. (F)
26. Interaction cross section is related to linear attenuation coefficient. (T)
27. Blood oximetry can be done using measurement of light attenuation at the isosbestic point. (F)
28. Resolution in the micron range can be obtained with optical coherence tomography. (T)
29. Raman scattering can be done with light of any wavelength. (T)
30. The use of T-rays is limited to superficial applications by their high attenuation. (T)
31. Emissivity of a blackbody changes only with wavelength. (F)
32. Human skin of any color behaves closely like an ideal blackbody. (T)
33. Having a glass window in an incubator room is not allowed to prevent UV radiation overexposure. (F)
34. Photons of UV light have sufficient energy to break down bilirubin molecules into more soluble forms. (T)
35. Exposure to blue light can be harmful to the eye. (T)
36. The cross section of the photoelectric effect is photon energy independent. (F)
37. Raman scattering of IR light involves scattered photons that do not have same original energy as the incident. (T)
38. Astigmatism is corrected by a spectacle lens that is symmetric about an axis through the center of the eye lens. (F)
39. In Compton scattering, the photon scattering angle can be calculated using the Klein–Nishina formula. (F)
40. The radiation energy from a heated atom depends on whether it is in a gas or a solid form. (T)

Part III. Solve the following problems:

41. Write the bioheat partial differential equation for each of the following cases: (each is a separate case):
    a. Assuming that there are no blood vessels inside the tumor. (Remove perfusion term)
    b. Assuming uniform temperature within the tumor volume (i.e., no spatial variation of temperature). (remove diffusion term and keep perfusion and absorption term)

42. A person at age 50 is fitted with bifocals with a +2 diopter strength bifocal lens. What are the closest and farthest distances of focus without the bifocal lens and with it? By the time the person is age 60, what are they with and without the same lens? (answer: similar to problem 14.41)

43. A beam of 100-keV photons from ^{241}Am scatters at 0° from some calcium atoms (A = 40). (answer: similar to problem 15.16)
    a. What is the energy of a Compton-scattered photon?
    b. What is the energy of a coherently scattered photon?
    c. What is the recoil energy of the atom in coherent scattering?

44. The differential scattering cross section for a beam of x-ray photons of a certain energy from carbon at an angle θ is 50×10^{-30} m^2 sr^{-1}. A beam of 10^6 photons strikes a pure carbon target of thickness 1 cm. The density of carbon is 2 g/cm^3, and the atomic weight is 12. The detector is a circle of 1-cm radius located 20 cm from the target. How many scattered photons enter the detector? (answer: similar to problem 14.11)

Best of Luck!