Medical Equipment I Midterm Exam – November 2010 (Model Answer)

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

Part I. Answer these questions by marking the best answer among the choices given (2.5 point each):

1. Artificial kidney filter membrane is … to urea.
   a) Permeable (*)
   b) Semipermeable
   c) Impermeable
2. Driving pressure is associated with the flow of … through membranes.
   a) semipermeable substances
   b) permeants (*)
   c) impermeable substances
3. In artificial kidney using cellophane membrane dialyzer, if ωRT is 10^{-5} m/s and body fluid volume is 50 liters, if the surface area of dialyzer is changed from 2 m^2 to 4 m^2, the treatment time will be …
   a) increased by a factor of 2
   b) decreased by a factor of 2 (*)
   c) decreased by a factor of 4
4. To transport a solute a long distance, … would be the most efficient phenomenon to do that.
   a) Solvent drag (*)
   b) Perfusion
   c) Diffusion
5. Fick's second law of diffusion can be driven from …
   a) Flux density and time
   b) Fick's first law of diffusion and Einstein relationship
   c) Fick's first law of diffusion and the conservation of mass (*)
6. The half-life time of the combined decay by three independent paths having the same decay constant of 1 s^{-1} is …
   a) 0.693 s
   b) 0.231 s (*)
   c) 0.347 s
7. The plot of the function f(x) = $x^{2.7}$ appears … on a log-log plot.
   a) linear (*)
   b) piecewise linear
   c) nonlinear
8. The plot of the function f(x)= e^{2x} has an intercept of … on a semi-log plot.
   a) 0
   b) 1 (*)
   c) x
9. Buoyancy force on aquatic animals in water is much less than that of terrestrial animals in air because …
   a) Density of aquatic animals is close to that of water (*)
   b) Density of terrestrial animals is close to that of air
   c) Volume of aquatic animals is much smaller than that of terrestrial animals
10. To reach double the diffusion distance, the diffusion time required must be …
    a) cut in half
    b) increased to double
    c) increased by 4 times (*)
11. Heavier particles in Brownian motion have kinetic energy that is … lighter particles of smaller size.
    a) higher than
    b) lower than
    c) the same as (*)

12. The First law of thermodynamics is equivalent to …
    a) Conservation of mass
    b) Conservation of energy (*)
    c) Thermal equilibrium
13. If the half-life of ^{99m}Tc is 6 hours, then it will reach … of its initial rate after 12 hours.
    a) half
    b) third
    c) quarter (*)
14. Headaches in renal dialysis can be reduced by …
    a) Reducing treatment time
    b) Increasing treatment time (*)
    c) Injecting urea in the blood
15. Consider a system with $N>100$ particles each having one of two states with probability 0.12 and 0.88 respectively. The total number of microstates in the system should be …
    a) $2N$
    b) 2^N (*)
    c) $<N$
16. Increasing extracellular fluid volume resulting from net water flow from capillaries results in …
    a) Edema (*)
    b) Osmotic fragility
    c) Osmotic dieresis
17. Clearance of a metabolite from the plasma through the kidneys follows … equation.
    a) Exponential decay (*)
    b) Linear decrease
    c) Logistic
18. Stirring sugar in water dissolves sugar faster than not stirring due to the process of …
    a) Solvent drag (*)
    b) Buoyancy forces
    c) Diffusion
19. The conservation of mass leads to …
    a) Fick's first law
    b) Continuity equation (*)
    c) Newton's second law
20. For a gas at standard temperature and pressure, if the volume of 1 mol is 22.4 liters and the radius of its molecules is 0.2 nm, then the mean free path is …
    a) 0.13 μm
    b) 0.10 μm
    c) 0.07 μm (*)
21. A process in which the change in a quantity Q with respect to time is constant is called …
    a) An exponential curve
    b) A quadratic curve
    c) A linear curve (*)
22. To reach a diatance of 3 mm, the diffusion time required must be … the time required for 1 mm.
    a) 3 times
    b) 2^3 times
    c) 3^2 times (*)
23. Countercurrent transport is preferred in hemodialysis because …
    a) It maintains a concentration difference along the whole path (*)
    b) It maintains a very high concentration difference that decays along the path
    c) It generates an additional diffusion energy

24. Ensuring essential communication in medical devices includes …
    a) people working harder to communicate with each other
    b) employing redundant methods of communicating vital information (*)
    c) a sufficiently loud auditory alarm signal
25. In the real world, the medical devices are demanded to …
    a) Have a limited user workload (*)
    b) To be less rugged
    c) To prioritize user input
26. People easily associate an turning a knob clockwise with an increase in the rate of gas flow because of ...
    a) Operation training
    b) Experience with similar devices
    c) Conventional mapping (*)
27. Typing the wrong character using the keyboard of a medical device is considered as …
    a) Slip (*)
    b) Lapse
    c) Mistake
28. Identification of use-related hazards can be done through …
    a) Analysis of predecessor and similar devices (*)
    b) User profiling
    c) Defining use environments
29. One method for use-related hazard mitigation strategies can be …
    a) FMEA
    b) Decision on whether risks are acceptable
    c) Modification of intended use (*)
30. An important task in risk management after the product is marketed is to …
    a) Track sales volumes compared to predecessor devices
    b) Track incidents of user complaints and device returns (*)
    c) Conduct usability testing

Part II. Mark the following statement as either True (T) or False (F) (1 point each):

31. Entropy is maximum at equilibrium. (T)
32. The Boltzmann factor is a special case of the Nernst equation. (F)
33. Systems of many particles that are in equilibrium tend to change with time away from equilibrium. (F)
34. Isolation of an infectious compartment can be done using an isolation system based on laminar flow. (T)
35. Diffusion is the main mechanism for oxygen transport from capillaries to cells. (T)
36. Osmotic pressure has a value only when using semipermeable or impermeable membranes. (T)
37. For a process with multiple decay paths, overall decay constant is larger than the decay constant of any of its components. (T)
38. The rate of increase of a quantity in an exponential growth process is proportional to that quantity. (T)
39. It is not possible to use classical mechanics to describe systems of many particles. (T)
40. Diffusion happens as a result of Brownian motion and solvent drag of particles in a fluid. (F)
41. When the probability of one of the available microstate is 1, the system is at equilibrium. (F)
42. Static equilibrium is reached when the balance of translational forces in any direction become zero. (F)
43. Device user interface designs usually violate a human factors engineering guideline. (T)
44. Medical device users always receive complete and proper training before using a given device. (F)
45. Designers should treat warnings as the main option for preventing problems in medical devices. (F)
46. Mistakes arise from applying the wrong knowledge when making a decision. (T)
47. After implementing design change to mitigate a risk, new risks may arise as a result of this change. (T)

Part III. Solve the following problems [10 points each]:

48. **[10 points]** Consider the problem of gas exchange between blood and air in alveoli. If the average radius for alveoli is 120 μm and that for capillaries is 5 μm and given that the diffusion constant in air is 2×10^{-5} and in water is 2×10^{-9} m^2s^{-1}, calculate time required for oxygen to diffuse from the center of an alveolus to the center of a blood capillary in contact with it in case of a patient with lung edema. Assume the lung edema to cause an additional small layer of fluid of thickness 1 μm between the capillary and the lung alveolus in contact with it. Assume also that the diffusion constants in blood and extracellular fluid are the same as that of water.
Solution: Same steps as problem 4.18 with only an added layer of the extra fluid between the alveolus surface and the capillary

49. **[10 points]** The potential energy of hydrogen nuclei in a magnetic field can be given as ($\gamma\ m\ B\ h/2\pi$) where γ is the gyromagnetic ratio (42.6 MHz/T), h is the Planck's constant given by 6.626×10^{-34} and B is the magnetic field, and m is the spin number that takes the values of either + ½ or – ½ . Calculate the probability of spins with m= ½ relative to that with m= – ½ at magnetic field B= 1 T and temperature of 300° K. Assume a unity density of states factor.
Solution: substitute in Boltzmann factor = (density factor=1) x exp(-(U1-U2)/k_BT) where U= (γ m B h/2π) and m=+1/2 or –1/2

50. **[10 points]** Consider two systems A, and A' that are in thermal contact with each other but are isolated from the rest of the universe. Let system A have 1 particle while system A' has three particles. The energy levels each particle may discrete values of integer multiples of u (that is, may take u, 2u, 3u, etc.). Let the total energy be U*= 5u. Compute the number of microstates for the whole system A*.

Solution:

System A		System A`		System A*
U	Ω	U'	Ω`	Ω*
1	1	4	3	3
2	1	3	1	1

$\Omega^*_{tot}= 4$

Best of Luck!