Medical Equipment I (Part 3) Term Exam – January 2013 (Model Answer)

Solve as Much as You Can – Maximum Grade for Part 3: 26 Points

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

1. 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 3 m^2 to 6 m^2, the treatment time will …
    a) increase by a factor of 2
    b) decrease by a factor of 2 (*)
    c) decrease by a factor of 4

2. Fick's second law of diffusion is derived based on …
    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 (*)

3. 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

4. The plot of the function f(x) = $\sqrt{x}$ appears … on a log-log plot.
    a) linear (*)
    b) piecewise linear
    c) nonlinear

5. 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

6. 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 (*)

7. The First law of thermodynamics is equivalent to …
    a) Conservation of mass
    b) Conservation of energy (*)
    c) Thermal equilibrium

8. 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 (*)

9. Increasing extracellular fluid volume resulting from net water flow from capillaries results in …
    a) Edema (*)
    b) Osmotic fragility
    c) Osmotic dieresis

10. Clearance of a metabolite from the plasma through the kidneys follows … equation.
    a) Exponential decay (*)
    b) Linear decrease
    c) Logistic

11. The conservation of mass leads to …
    a) Fick's first law
    b) Continuity equation (*)
    c) Newton's second law

12. A process in which the change in a quantity Q with respect to time is proportional to Q is called …
    a) An exponential curve
    b) A quadratic curve

c) A linear curve (*)
13. To reach a distance of 3 mm, the diffusion time required must be … the time required for 1 mm.
   a) 3 times
   b) 8 times
   c) 9 times (*)
14. 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

Part II. Mark the following statement as either True (T) or False (F) (0.5 point each):

15. Isolation of an infectious compartment can be done using an isolation system based on laminar flow. (T)
16. Osmotic pressure has a nonzero value only when using semipermeable or impermeable membranes. (T)
17. Exponential growth can be plotted as a linear curve using log-log plots (F)
18. Work is calculated as the area under the pressure-volume curve (T)
19. Diffusion happens as a result of Brownian motion of particles in a fluid. (T)
20. The properties of capillary-brain barrier in the reason for headaches in renal dialysis (T)
21. The net transport of water across a semipermeable membrane depends only on osmotic pressure (F)
22. Particle flux is defined as the total volume of material transported per unit time (F)

Part III. Solve the following problems:

23. **[2 points]** Compute an approximate figure for the number of cells in a cat. Assume any missing information.

   Assume the shape and dimensions of a typical cat and a typical cell and divide the two.

24. **[3 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 2 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 (acts very much like blood as far as diffusion parameters)

25. **[3 points]** If the distribution of driving and osmotic pressures along a capillary in a normal person is as shown to the right, determine whether edema will occur to a patient that has lower amounts of large proteins in his blood that cannot pass through capillary membrane. Illustrate your answer by showing how the patient case would look like on the figure to the right.

   Lower amounts of proteins leads to lower osmotic pressure inside capillary π, which leads to higher driving pressure (P$_{total}$ (constant) = Pd (higher)+ π (lower)). This mean that the effective outward flow will be higher leading to edema.