Medical Equipment I Mid-Term Exam – Solution Guide

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

November 22, 2007

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

Q1. Answer the following questions by marking the best answer among the choices given (2 points each):

1. When an object is at static equilibrium (i.e., not moving), the sum of forces in the *z*-direction is …
   a. Zero (*)
   b. Equal to its mass
   c. Equal to its weight
2. The conservation of mass leads to …
   a. Fick's first law
   b. Continuity equation (*)
   c. Newton's second law
3. The conservation of energy is stated in …
   a. First law of thermodynamics (*)
   b. Newton's third law
   c. Entropy
4. The total decay in the case of multiple decay paths is equal to the … of individual rates.
   a. multiplication
   b. sum (*)
   c. sum of inverse
5. The clearance of substance X from plasma is defined as …
   a. The volume of X removed from plasma per unit time
   b. The volume of plasma from which X is completely removed per unit time (*)
   c. The time constant of the process of plasma and substance X separation.
6. If the half life of ^{99m}Tc is 6 hours, then the length of time required for it to reach ¼ is … hours.
   a. $6\sqrt{2}$
   b. 6 ln(2)
   c. 12 (*)
7. A biological system represented by the differential equation $\frac{dy}{dx} = x^2 y$ appears … on semilog plot.
   a. Linear
   b. Quadratic
   c. None of the above (*)
8. In order to make the analysis of a system represented by the equation $y=\alpha x^3$, we use …
   a. Semilog plot

b. Log-log plot (*)
c. Linear plot

9. Consider a system with N particles each having one of two states with probability 0.2 and 0.8 respectively. The total number of microstates in the system is …
   a. 2^N (*)
   b. 2N
   c. N-1
10. The amount of mass transported across an imaginary surface per unit area per unit time is …
   a. Mass flux density (*)
   b. Particle fluence
   c. Volume fluence
11. Mean free path in liquids is different from gases because of the presence of …
   a. Diffusion
   b. Drag forces (*)
   c. Brownian motion
12. Fick's second law of diffusion combines Fick's first law and …
   a. Solvent drag
   b. Continuity equation (*)
   c. Viscosity
13. For a gas at standard temperature and pressure, if the volume of 1 mol is 22.4 liter 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 (*)
14. The plot of the sum of two exponential decays on semilog paper appears as a linear curve …
   a. everywhere
   b. for very large values of time (*)
   c. for very small values of time
15. The buoyant force on animals in the air is …
   a. Very small (*)
   b. Approximately the same as their weight
   c. Much larger than their weight
16. The threshold of turbulent flow is determined by …
   a. Poiseuille equation
   b. Stoke's equation
   c. Reynolds number (*)
17. A process in which the change in a quantity Q with respect to time is proportional to time is …
   a. An exponential curve
   b. A quadratic curve (*)

c. A linear curve

18. Macrostates of a biological system with many particles may include all of the following except …
    a. Pressure
    b. Temperature
    c. Particle energy (*)
19. At equilibrium, probability of all microstates is …
    a. Equal (*)
    b. Zero
    c. 1
20. A particular disease in rabbits 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 rabbit has 3 X chromosomes is …
    a. 0.0001
    b. 0.00001
    c. 0.000001 (*)
21. To reach double the diffusion distance, the diffusion time required must be …
    a. half
    b. Double
    c. Four times (*)
22. The solution of the Fick's second law of diffusion is … in shape.
    a. Gaussian (*)
    b. Quadratic
    c. Sinusoidal
23. Heavier particles in Brownian motion move … lighter particles.
    a. Faster
    b. Slower (*)
    c. As fast as
24. One of the industrial biomedical applications of laminar flow is …
    a. Isolation of an infectious compartment using laminar air flow (*)
    b. Exchange of metabolites in hemodialysis systems
    c. Transportation of particles in injections.
25. Rotational equilibrium relies on a balance of …
    a. Torques (*)
    b. Forces
    c. energies

Q2. Mark the following statement as either True (T) or False (F) (1 point each):

1. In Brownian motion, particle velocity is constant and given by $\sqrt{3k_BT/m}$. (F)

2. Mean free path is much larger than particle size in gases. (T)
3. In diffusion between two solutions across a membrane, Brownian motion stops at equilibrium. (F)
4. Drag forces are determined by the Boltzmann factor in liquids. (F)
5. The entropy of a system is equal to the sum of entropies of its subsystems. (T)
6. Aquatic animals are essentially "weightless" because of viscosity in the water. (F)
7. Water is not a compressible fluid. (T)
8. Adiabatic systems do not involve heat flow. (T)
9. Systems that are not at equilibrium tend to change until all its microstates have equal probability. (T)
10. The derivative of entropy with respect to energy is equal to the temperature. (F)
11. In Nernst equation, the voltage across the membrane is the result of the Boltzmann constant. (F)
12. Translational kinetic energy of any particle moving in a Brownian motion is the same. (T)
13. Brownian motion is a direct consequence of the diffusion phenomenon. (F)
14. Heavier solutes diffuse slower than lighter ones. (T)
15. Diffusion is the main mechanism for oxygen transport between capillaries and alveoli. (T)

Q3: Consider two systems *A* and *A'* that are in thermal contact with each other but are isolated from the rest of the universe. System *A* has <u>one</u> particle while system *A`* has <u>two</u> particles. The energy levels each particle may have u, $2u$, $3u$, etc. Let the total energy be $U^* = 5u$. Compute the number of microstates for the whole system.

Solution:

System A		System A`		System A*
U	Ω	U	Ω`	Ω*
1u	1	4u	3	3
2u	1	3u	2	2
3u	1	2u	1	1
				$\Omega^*_{tot}=6$

Q4: Consider a system with 1000 particles where the potential energy is given by $m.E$ where E is 10^{-20} and m may take the values of 1 and 2 only for states 1 and 2 respectively. Assuming the density of states factor is given by 0.8 (state 1 relative to state 2), calculate the relative probability of finding the system in state 1 relative to state 2 at temperature 300 °K.

Solution: Boltzmann Factor with G =1, Us – Ur= (1 E – 2 E).

Q5: If a complication of a disease causes the dilation of capillaries to have a radius of 6 μm instead of its normal size of 4 μm and assuming the radius of alveoli to be 80 μm, compute the time for oxygen to diffuse from the center of an alveolus to the center of a capillary. Assume the diffusion constant for oxygen in air to be 2×10^{-5} m^2/s and in water to be 2×10^{-9} m^2/s. [Hint: consider 1D diffusion]

Same steps as problem 4.18