Medical Equipment I Mid-Term Exam MODEL ANSWER
November 19, 2011

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 [2 points each]:

1. If we define "Third-Life Time $T_{1/3}$" as the time required for a quantity to decrease to 1/3 its value, the quantity will decrease to … its original value by the end of 2 $T_{1/3}$.
   a. 1/9 (*)
   b. 1/6
   c. 1/4

2. In a model that consists of the sum of two exponential decay curves, it is possible to estimate the … component first then the other one.
   a. Fast
   b. Slow (*)
   c. Large

3. In a multiple decay process, the half-life time of the process is … the half-life times of its individual component decay processes.
   a. Larger than
   b. Smaller than (*)
   c. Same as

4. In Log-Log plots, the intercept is estimated as the y-value for which x is equal to …
   a. 1 (*)
   b. 0
   c. e

5. In semi-log plots, scaling an exponential curve by a factor of 3 results in …
   a. Change in slope by log(3)
   b. Change in intercept by a multiplication by log(3) on the scale
   c. Change in intercept by a shift of 3 on the scale (*)

6. Consider 10 gas molecules in a box partitioned in 2 imaginary partitions (i.e., no physical wall) taking up 1/3 of the box (right) and remaining 2/3 of the box (left). The probability that there are no gas molecules in the left partition is equal to:
   a. 0
   b. 1.7×10^{-5} (*)
   c. 0.017

7. A system consisting of N particles each with an energy E will have a total energy of …
   a. N E (*)
   b. $N^2 E$
   c. $N^{0.5} E$

8. If a given system's macrostates change with time, then it must be …
   a. At equilibrium
   b. Getting closer equilibrium (*)
   c. Getting further from equilibrium
9. Even though the compressibility of water is very small, its variations is the basis for such important biomedical applications as …
   a. ultrasound imaging (*)
   b. using a cane
   c. lung mechanics
10. If a system exists only in one of two states with entropy values S1 and S2 with S1>S2, then its equilibrium state is the one with entropy …
    a. S1 (*)
    b. S2
    c. S1+S2
11. The Fick's first law of diffusion …
    a. computes the force that drives solute molecules to move from higher to lower concentration
    b. assumes independent random Brownian motion for each of the solute molecules (*)
    c. relies on continuity equation to derive its formula
12. Heavier particles in Brownian motion have root-mean-squared velocity that is … lighter particles.
    a. faster than
    b. slower than (*)
    c. the same as
13. To accommodate medical device users' needs and preferences, …
    a. rely exclusively on thought leaders to put the product specifications
    b. let users set the pace while working with the medical device (*)
    c. plan a comprehensive training for users
14. Positive transfer in human factors engineering means …
    a. designers using past positive experience when designing a new device user interface
    b. positive feedback from usability testing making devices more error-tolerant
    c. users applying past experience to a new device, reducing their learning time (*)
15. Designers should distinguish power cable receptacles from sensor cable receptacles to …
    a. reduce signal noise
    b. increase device appeal
    c. reduce use errors (*)
16. Developing compatible medical device designs involve …
    a. Knowledge of other devices in contact with the target device in the clinical environment
    b. Accommodating mental models (*)
    c. Effective choice of biomaterials for safety
17. Undesirable events resulting from the interaction between a user and a device is called …
    a. Slip
    b. Lapse
    c. User error (*)
18. Omitting steps in a device operating procedure as a shortcut is classified as …
    a. Slip
    b. Lapse
    c. Mistake (*)

19. With respect to medical devices, harm does not include …
    a. Delayed treatment
    b. Fatigue of device operator (*)
    c. Injury to patient
20. Fault tree analysis (FTA) differs from failure mode effects analysis (FMEA) is that …
    a. FMEA works from the bottom up, while FTA starts from top-level hazards down. (*)
    b. FMEA involves brainstorming that is not required in FTA
    c. FTA is more suitable for clinical environment whereas FMEA is best for industrial settings

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

21. Log-Log plots are ideal to draw general polynomial curves. (F)
22. Human are weightless in outer space because of higher buoyancy forces there than on Earth. (F)
23. A system contained in adiabatic walls and partitioned in two allows exchange of heat between its partitions. (T)
24. Adding heat to a system involves a change in the average position of energy levels of its particles. (F)
25. Ergodicity means equivalence of time and ensemble averages of a random process. (T)
26. If an isolated system is at equilibrium, there is an equal probability for each one of its accessible microstates. (T)
27. Stirring sugar in water distributes sugar molecules throughout faster due to solvent drag. (T)
28. Formula to estimate mean free path in liquids is the same as that of gases. (F)
29. Equilibrium is the least random state of a system. (F)
30. Conservation of mass serves as the basis for the derivation of continuity equation. (T)
31. The rate of decrease of a quantity in an exponential decay process is proportional to that quantity. (T)
32. Heat diffusion between two systems in contact can be describes by Fick's first law. (T)
33. Designers should anticipate medical device migration into different use environments. (T)
34. It is acceptable for designers to deviate from industry standards to make their device unique. (F)
35. Medical devices designed with multiple operational modes must clarify the present operating mode to the user. (T)
36. It is necessary to mitigate abnormal use by a user who actually intends to use a device incorrectly. (F)
37. Usability test participants should include one of the designers in addition to doctors and nurses. (F)
38. Intended use of a medical device includes its present clinical applications. (T)
39. Verification must be done by clinicians whereas validation is mainly done by design engineers. (F)
40. Designers should perfect the details of a design before applying high-level design principles. (F)

Part III. Solve the following problems (10 points each):

41. Consider two systems A and A' in thermal contact with each other and contained within common adiabatic walls. The first system has 3 particles while the second has 2 particles and both systems cannot exchange particles or work. The total energy of the system is 10u with possible energy values for each particle being integer values of u (i.e., 1u, 2u, etc.). Compute the total number of microstates in the system.

U	Ω	U'	Ω'	Ω^*
3	1	7	6	6
4	3	6	5	15
5	6	5	4	24
6	10	4	3	30
7	15	3	2	30
8	21	2	1	21

Ω^*total=   126

42. The potential energy of a system is given as exp(m B^2) where B is the magnetic field, and m is the spin number that takes the values of either + 1 or −1. The kinetic energy of both states is assumed to be the same. Calculate the probability of spins with m= 1 relative to that with m= −1 at a magnetic field B= 1 T and temperature of 300°K.

Us= (exp(+B^2)+K.E.) , Ur= (exp(+B^2)+K.E.) with K.E. the same and apply in Boltzmann factor

43. Consider a patient who just had a surgical procedure to repair a fracture of the head of the femur. Consider the case of using a cane with tip 30 cm away from the center line and let the leg be 10 cm away from that center line. Compute the force on the head of the femur from the acetabulum with the cane assuming that the cane supports a weight of 30 Kg. Assume any missing information.
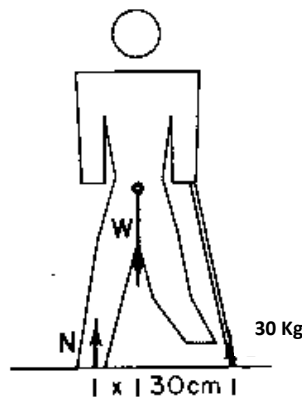
Same as example in lecture but with cane support constant = 30Kg instead of W/6. Derive translational and rotational equilibrium and get the force on the acetabulum as a function of W.

Best of luck!