Medical Equipment I Mid-Term Exam – Solution Guide
Time Allowed: 1 ½ Hours – Open-Book/Open-Notes
November 30, 2008

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 pts each):

1. The continuity equation is a direct result of …
   a. Static equilibrium
   b. Conservation of mass (*)
   c. Newton's second law
2. The conservation of energy is equivalent to …
   a. Entropy
   b. Thermal equilibrium
   c. First law of thermodynamics (*)
3. 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
4. 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 (*)
5. A system represented by the differential equation $\frac{dy}{dx} = 100x^2$ appears … on log-log plot.

   a. Linear (*)
   b. Quadratic
   c. None of the above
6. To analyze a system represented by the equation $y = c_1 e^{-\alpha x} + c_2 e^{-\beta x}$, we use …
   a. Semilog plot (*)
   b. Log-log plot
   c. Linear plot
7. Consider a system with *N>100* particles each having one of two states with probability 0.2 and 0.8 respectively. The total number of macrostates in the system should be …
   a. 2^N
   b. $2N$
   c. $<N$ (*)
8. 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
9. 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.
10. Formula to estimate mean free path in liquids is different from that of gases because …
    a. Distance between molecules is too close and violates independence assumption (*)
    b. Laminar flow does not allow molecules to collide

  c. Brownian motion is different in fluids

11. Fick's second law of diffusion is derived from Fick's first law and …
  a. Solvent drag
  b. Continuity equation (*)
  c. Viscosity

12. 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 (*)

13. The plot of $(3x + 2x^3)$ on log-log paper appears as a …
  a. Cubic curve everywhere
  b. Linear curve for very large values of time (*)
  c. Quadratic curve for very small values of time

14. The buoyant force on planes in the air should be …
  a. Very small compared to its weight (*)
  b. Approximately the same as their weight to make the plan fly
  c. Much larger than their weight to allow the plane to move higher up

15. A process in which the change in a quantity Q with time is proportional to Q is …
  a. An exponential curve (*)
  b. A quadratic curve
  c. A linear curve

16. Microstates of a biological system with many particles may include …
  a. Pressure
  b. Temperature
  c. Particle energy (*)

17. When the probability of all microstates is equal, the system is at …
  a. Equilibrium (*)
  b. Entropy
  c. Random Brownian motion

18. 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 (*)

19. To reach double the diffusion distance, the diffusion time required must be …
  a. half
  b. Double
  c. Four times (*)

20. The solution of the Fick's second law of diffusion is … in shape.
  a. Gaussian (*)
  b. Quadratic
  c. Sinusoidal

21. Bigger particles in Brownian motion move … smaller particles of the same mass.
  a. Faster
  b. Slower
  c. As fast as (*)

22. Static equilibrium implies the balance of … in the object under study.

a. Torques
b. Forces
c. Both torques and forces (*)

23. C8051F020 microcontroller memory location 0F0H when accessed using direct addressing mode refers to …
    a. Special function register (*)
    b. Indirect memory address
    c. Immediate value

24. For high timing accuracy applications, one should use a system clock based on …
    a. RC oscillator
    b. Crystal oscillator (*)
    c. The microcontroller's own internal oscillator

25. Watchdog timer can be used to …
    a. Schedule periodic check on the status of a process
    b. Reset the microcontroller when runs out of control (*)
    c. Measure time critical events

26. Using a 3.3V microcontroller, one can make a GPIO pin provide output with TTL levels (i.e., 0V for logic 0 and 5V for logic 1) using …
    a. A push-pull output mode and an amplifier at the output of the pin.
    b. A push-pull output mode and a pull-up resistor connected to 5V.
    c. An open-drain output mode and a pull-up resistor connected to 5V. (*)

27. GPIO pins can be used for bidirectional data transfer when they are configured as …
    a. Open-drain mode with internal weak pull-ups (*)
    b. Open-drain mode with external weak pull-ups
    c. Push-pull mode

28. When the microcontroller running from an external crystal oscillator finds out that its external clock source is invalid, …
    a. It switches automatically to internal oscillator
    b. It can be configured to reset (*)
    c. It causes a flag to be raised for the program to repair the problem.

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

1. In Brownian motion, particle velocity changes only when the temperature changes.   (F)
2. Mean free path is much larger than particle size in gases. (T)
3. In solute diffusion between two solutions across a permeable membrane, Brownian motion stops at steady-state. (F)
4. Drag forces are determined by the Boltzmann factor in liquids. (F)
5. The entropy of a system is equal to the root mean square of entropies of its subsystems.(T)
6. Aquatic animals are essentially "weightless" because of drag forces in the water. (F)
7. Ideal adiabatic systems involve only mechanical work. (T)
8. The derivative of entropy with respect to energy depends on the temperature. (T)
9. Diffusion is a direct consequence of the Brownian motion phenomenon. (T)
10. Steady-state of the diffusion process takes same amount of time for heavier solutes as lighter ones. (F)
11. Laminar flow is the main mechanism for oxygen transport to capillaries through alveoli. (F)
12. The C8051F020 can be configured to start using an external crystal oscillator upon reset. (F)
13. UART serial communication requires the microcontroller to use an external crystal oscillator (T)
14. The output from bitwise operations is always a Boolean value. (F)

15. The memory locations above 080H can only be accessed using indirect addressing. (T)

Q3. Denote the following C8051F020 microcontroller instructions as either being true (T) or false (F) assembly instructions. [2 point each]

```
1.      ADD      A, F0H          (T)
2.      MOV      70H, A          (T)
3.      MOV      @R2, A          (F)
4.      ADD      A, #300H        (F)
5.      SWAP     P0              (F)
6.      DJNZ     30H, 70H        (T)
7.      CPL      P5.4            (F)
8.      COUNT    EQU  R3         (F)
9.      INC      R7              (T)
10.     MUL      AA              (F)
```

Q4. [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. System A has **two** particle while system A` has **three** particles. The energy levels each particle may have u, $2u$, $3u$, etc. Let the total energy be $U^*= 7u$. Compute the number of microstates for the whole system.

Solution:

System A		System A`		System A*
U	Ω	U'	Ω`	Ω*
2u	1	5u	6	6
3u	2	4u	3	6
4u	3	3u	1	3
				$\Omega^*_{tot}=18$

Ω`(4u)= 3
{1,1,2},
{1,2,1},
{2,1,1}

Ω`(5u)= 6
{1,1,3},
{1,3,1},
{3,1,1},
{2,1,2},
{2,2,1},
{1,2,2}

Q5. [5 points] The potential energy of hydrogen nuclei in a magnetic field is equal to (γ m B h/2π) 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$_B$T) where U= (γ m B h/2π) and m=+1/2 or –1/2

Q6. [6 Points] Write C8051F020 assembly code lines to do the following tasks:
    a. a delay of 100 clock cycles
    b. Inverting bit P5.4
    c. Inverting bit P1.6