Biomedical Engineering Department
Cairo University

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

Medical Equipment I Term Exam MODEL ANSWER
January 2010

<u>**Solve as Much as You Can – Maximum Grade: 100 Points**</u>

<u>**Part I. Answer the following questions by marking the best answer among the choices given [1 points each]:**</u>

1. For myelinated fibers, doubling the fiber radius results in … the speed.
   a) half
   b) double (*)
   c) quadruple

2. Dividing the space constant by the time constant in the electrotonus model results in a quantity that is related to …
   a) Speed of conduction (*)
   b) Saltatory conduction
   c) Passive spread

3. Action potential in axons results from …
   a) Changes in membrane Nernst potentials
   b) Cable equation of conduction
   c) Changes in membrane permeability of certain ions (*)

4. Capacitance per unit area of an axon of thickness 2 μm and assuming dielectric constant κ to be 7 is … μF/m.
   a) 30   (*)
   b) 3
   c) 0.3

5. Resting membrane potential is identical to that of …
   a) Sodium
   b) Potassium
   c) Chlorine   (*)

6. Kirchhoff's second law (or voltage law) is equivalent to …
   a) Conservation of electric charge
   b) Conservation of energy (*)
   c) Conservation of mass

7. Artificial kidney filter membrane is … to plasma.
   a) Permeable
   b) Semipermeable
   c) Impermeable   (*)

8. Driving pressure is associated with the flow of … through membranes.
   a) semipermeable substances
   b) permeants (*)
   c) impermeable substances

9. In artificial kidney using cellophne membrane dialyzer, if ωRT is 1×10^{-5} m/s and body fluid volume is 40 liters, if the surface area of dialyzer is decreased from 4 m^2 to 2 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 e^2

10. The concentration of water deep in oceans … with depth.
    a) Decreases exponentially
    b) Increase exponentially (*)
    c) Remains constant

11. To transport a solute a long distance, … would be the most efficient phenomenon to do that.
    a) Solvent drag (*)
    b) Perfusion
    c) Diffusion

12. 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 (*)

13. 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

14. The plot of the function f(x)= $x^{3.43}$ appears … on a log-log plot
    a) linear   (*)
    b) piecewise linear
    c) nonlinear

15. The plot of the function f(x)= $e^{2.2x}$ has an intercept of … on a semi-log plot.
    a) 0
    b) 1 (*)
    c) x

16. 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

17. 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 (*)

18. 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 (*)

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

20. 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 (*)

21. A system represented by the differential equation $\dfrac{dy}{dx} = 100x^2$ appears … on log-log plot.

    a) Linear (*)
    b) Quadratic
    c) None of the above

22. 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

23. 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) $<N$ (*)

24. Increasing extracellular fluid volume resulting from net water flow from capillaries is called …
    a) Edema   (*)
    b) Osmotic fragility
    c) Osmotic dieresis

25. The most challenging design problem in ESU is …
    a) Reaching the desired power and voltage levels (*)
    b) Wave shaping
    c) Electrode design

26. The effect of ESU to raise the temperature of the tissue can be modeled using …
    a) Ohm's law
    b) Diffusion equation
    c) Bioheat equation (*)

27. Cardioverters are different from defibrillator in that …
    a) It applies an AC shock rather than a DC shock
    b) It synchronizes the defibrillation pulse with ECG (*)
    c) It has a built in patient monitor

28. … type ventilator is considered physiologically better than other types.
    a) Negative pressure (*)
    b) Positive pressure
    c) Volume cycled

29. Below the Let-Go current, … occur.
    a) Respiratory paralysis and pain
    b) Burns
    c) No irreversible effects (*)

30. The basic idea of electrical isolation is to …
    a) Connect everything around the patient to Earth
    b) Break ohmic continuity of electric signals between input and output (*)
    c) Use low voltage power sources

31. Time gain compensation is used to compensate for the effects of …
    a) Speed of ultrasound
    b) Attenuation (*)
    c) Acoustic impedance

32. It is possible to detect blood velocity using …
    a) B-Mode
    b) M-Mode
    c) Doppler-Mode (*)

33. The most common method of noninvasive blood pressure monitoring is …
    a) Mercury meter
    b) Oscillometric method (*)
   c) Electro-optic method

34. The main problem with x-ray imaging compared to CT is that …
     a) It offers a static image
     b) It offers a projection image (*)
     c) It suffers from attenuation

35. Angiography is …
     a) The imaging of blood perfusion
     b) The estimation of blood flow rate
     c) The imaging of blood vessels (*)

36. Hemodialysis must use … to perform its function.
     a) Diffusion
     b) Ultrafiltration
     c) Both of the above (*)

37. Arterial blood line is …
     a) The line leading from the patient to the hemodialysis machine (*)
     b) The line returning to the patient from the hemodialysis machine
     c) Any of the above as long as it is connected to an artery in the patient

38. A problem in the dialyzer can be detected using …
     a) Air bubble detector
     b) Conductivity monitor
     c) Blood leak detector (*)

39. Blood pump is usually selected to be … type.
     a) Proportioning pump
     b) Peristaltic pump (*)
     c) Flow pump

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

Part II. Mark the following statement as either True (T) or False (F) (½ point each):

41. Electric field within a dielectric is less than that of free space due to the polarization field. (T)
42. Myelinated fibers with radius more than 600 nm are not found in the body. (F)
43. Expected conduction speed based on the passive spread model agrees in form with empirical model. (T)
44. The electric field of the resting membrane potential at a point 1 cm away from its surface is zero. (T)
45. When fluids are moving in the same direction in hemodialysis, the transport efficiency will be better. (F)
46. Entropy is maximum at equilibrium. (T)
47. The Boltzmann factor is a special case of the Nernst equation. (F)
48. Systems of many particles that are not in equilibrium tend to change with time until reaching equilibrium. (T)
49. Isolation of an infectious compartment can be done using an isolation system based on heat flow. (F)
50. Desiccation is the drying of tissue due to the evaporation of intracellular fluids. (T)
51. Dispersive electrode in bipolar ESU has to be maintained in good contact to the ground. (F)
52. No ESU lead isolation system can be considered as perfect. (T)
53. Lithotripsy uses electric discharge to generate a shock wave. (T)
54. Duplex mode includes B-mode and PW-Doppler mode in ultrasound imaging. (T)
55. Pulse oximeters can be used to estimate the heart rate. (T)
56. Skin pigmentation causes problems for pulse oximeters that use normalization. (F)
57. Capnography can be done noninvasively. (T)
58. Respiration signal can be estimated from the ECG electrodes. (T)
59. Very strict control of the temperature of dialysate may not be necessary all the time in hemodialysis. (F)
60. Brownian motion in gases involves frequent collision of particles moving in random directions. (F)
61. The macrostate of a system is determined by specifying all external parameters and the total energy. (T)
62. Diffusion occurs with permeable membranes. (T)

63. The derivative of entropy with respect to time is equal to the inverse of temperature. (F)
64. Solvent drag is the main mechanism for oxygen transport from capillaries to cells. (F)
65. Hemodialysis systems must be able to monitor the presence of air bubbles in venous blood line. (T)

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66. [8 Points] Consider a patient who just had a surgical procedure to repair a fracture of the head of the femur. Consider the two cases with and without 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 (left) and without (right)the cane assuming that the cane supports a weight of 20 Kg. Assume any missing information.

With a Cane   Without a Cane
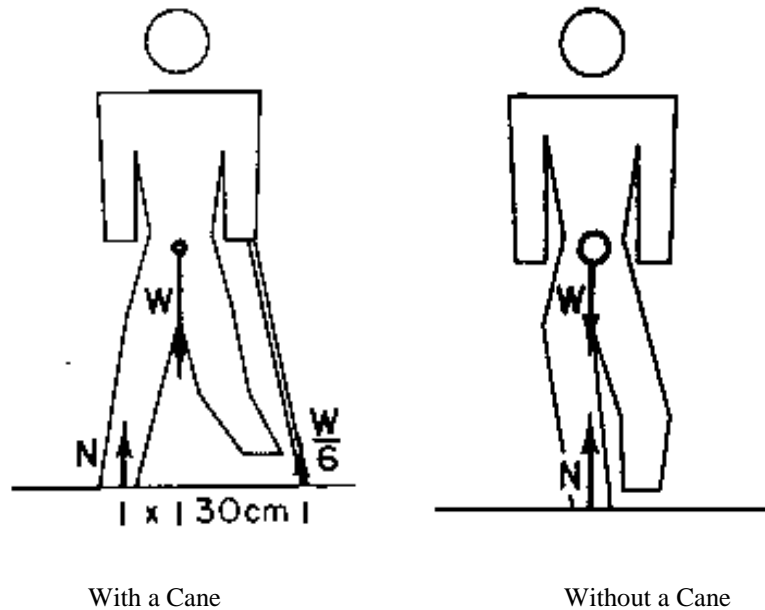
Solution: similar to the example in Chapter 1 but with different numbers.

67. **[8 Points]** Estimate the functional relationship between x and y for the 5 curves represented in the following plots:
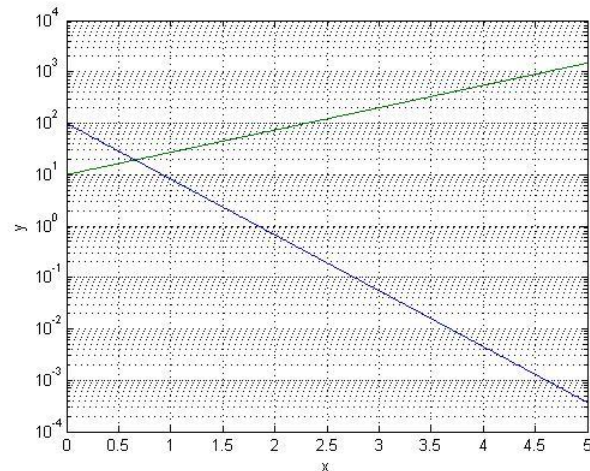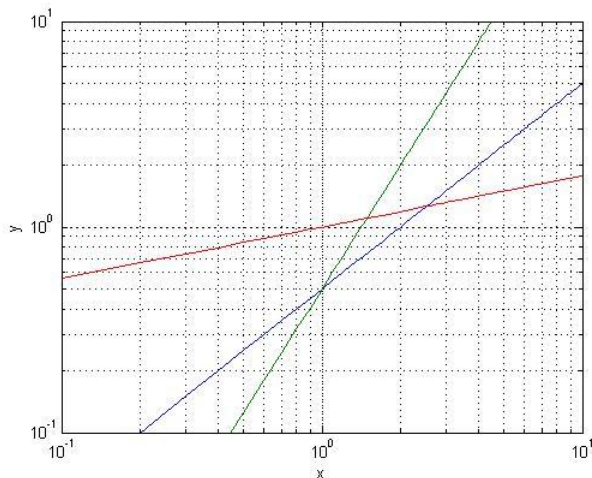
Matlab Code that was used to generate these plots is below (for you to generate the same figures if you want). See the functional forms of the 5 lines from the equations in that code. You should use the methods from Chapter 2 to calculate these forms from the figures.
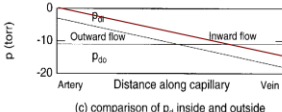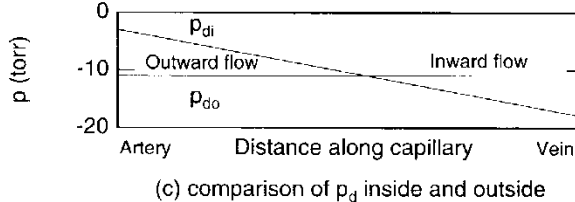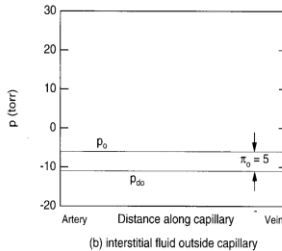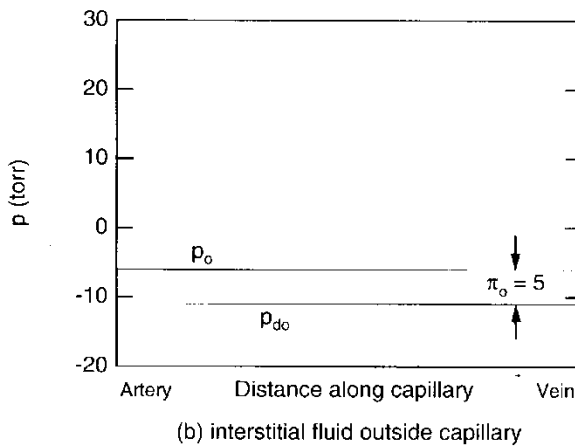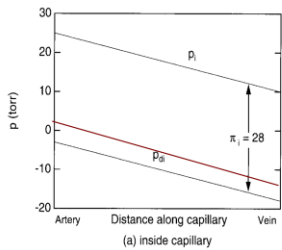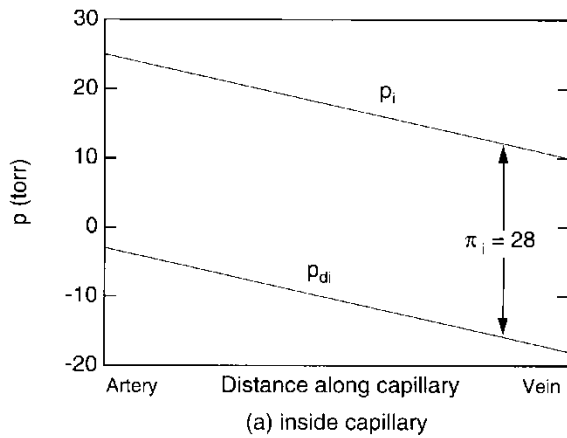
```
x=0.1:0.1:10;
y= 0.5*x;                    % first curve on log-log plot
y1= 0.5*x.^2;                % second
y2= x.^0.25;                 % third
figure(1)
```

```
loglog(x,y,x,y1,x,y2)
axis([0.1 10 0.1 10])
grid on
xlabel('x')
ylabel('y')

x= 0:0.01:5;
y3= 100*exp(-2.5*x);          % first curve on semilog plot
y4= 10*exp(x);                % second
figure(2)
semilogy(x,y3,x,y4);
grid on
xlabel('x')
ylabel('y')
```

68. **[8 points]** Consider the case of a particular disease where the patient has a high blood pressure and his nephrons in one kidney leak proteins into the urine. Modify the plots for capillary and extracellular fluid pressure plots to reflect this situation and provide your opinion about the symptoms that will likely occur to this patient as a result of such problems.

(a) inside capillary

(b) interstitial fluid outside capillary

(c) comparison of p_d inside and outside

Solution: What will happen is shown in the small figure shown. As a result of the changes, it is likely that edema will occur.

Best of Luck!