UNIVERSITY OF GHANA

BSC. ENGINEERING

FIRST SEMESTER EXAMINATIONS: 2017/2018

DEPARTMENT OF BIOMEDICAL ENGINEERING

BMEN 401: ENGINEERING PRINCIPLES OF HUMAN ANATOMY & PHYSIOLOGY (2 CREDITS)

INSTRUCTIONS:
ANSWER THREE (3) QUESTIONS

TIME ALLOWED: TWO (2) HOURS

1. **a.** Following a 650 mg intravenous bolus dose of drug to a 65 kg subject, the plasma drug concentration was found to decline bi-exponentially. The equation that best described the drug kinetic was:

$$C = 67e^{-14t} + 33e^{-3t}$$

where **t** is in hours and C is in μg/ml.

Calculate the following:

i. The apparent volume. [5 marks]

ii. The plasma level of the drug after 30 minutes of intravenous dose. [5 marks]

iii. The infusion rate if the drug is to be given at constant rate, the desired steady state is 20 μg/ml and the elimination rate is 6.33 /hr. [5 marks]

b. If the single compartment model (Figure 1) is used to describe a constant infusion rate of drug where Ro is the infusion rate and K_E is the elimination rate.

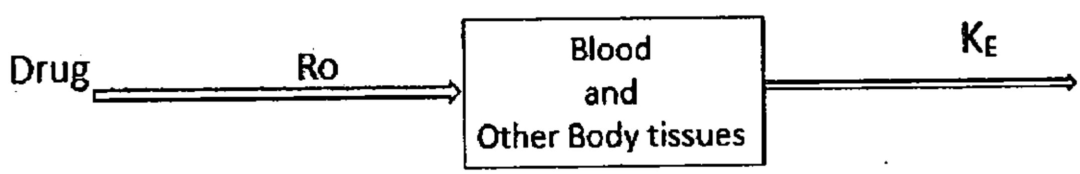

Figure 1: Single Compartment Model

Show by means of diagrams the following:

i. The plasma drug concentration with infusion rate Ro until saturation. [2 marks]

ii. The plasma drug concentration with infusion rate 2Ro until saturation. [2 marks]

iii. The plasma drug concentration when the infusion is stopped at time T. [2 marks]

iv. Explain how you would find the elimination rate constant. [2 marks]

c. State four specific purposes of modelling. [2 marks]

2. Table 1 gives the plasma drug concentrations (Cp) obtained following an intravenous bolus administration of a 250 mg dose of a drug that exhibited the characteristics of a one-compartment model and was eliminated exclusively by urinary excretion.

Table 1: Plasma Concentrations

Time (h)	Plasma Concentration (ug mL^{-1})
0.5	68.0
1.0	54.0
2.0	30.0
3.0	18.5
5.0	6.0
7.0	1.8

a. Plot a suitable graph of the data. [5 marks]

Using the graph, determine the following;

b. The elimination half-life ($t_{1/2}$). [5 marks]

c. The overall elimination rate constant (K). [5 marks]

d. The initial plasma concentration, (Cpo). [5 marks]

e. The apparent volume of distribution (V). [5 marks]

f. The drug plasma concentration at 75 min following the administration of a 2.5 $mgkg^{-1}$ dose to a subject weighing 70 kg. [5 marks]

3. **a.** What is Donnan equilibrium and how is it different from thermodynamic equilibrium? [3 marks]

b. Name two effects of Donnan equilibrium in a cell. [2 marks]

c. The diagram (Figure 2a and 2b) show two compartments separated by a biological membrane with NaCl solution in one side and Na^+ and A^- ions on the other side. If the membrane is only permeable to Na^+ and Cl^-, calculate the concentrations of ions in side I and side II after equilibrium. [10 marks]

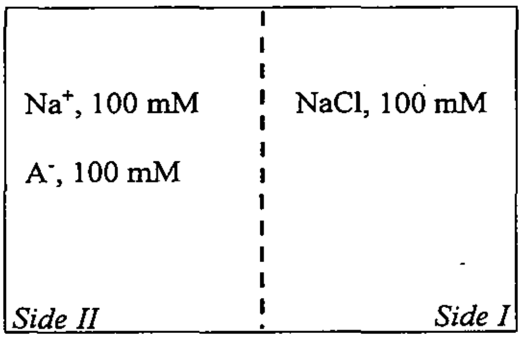

Figure 2a: Initial distribution (time = 0)

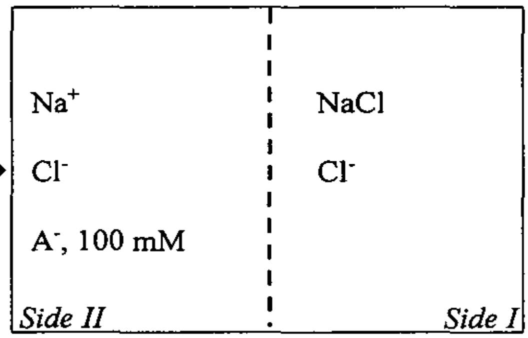

Figure 2b: Distribution at equilibrium

d. The deviation g(t) of a subject's blood glucose concentration can be modeled to satisfy the second order differential equation below.

$$\frac{d^2 g}{dt^2} + 2\alpha \frac{dg}{dt} + \omega_o^2 g = Q(t)$$

Where α is the decay constant, ω_0 is the natural frequency of the subject and Q(t) is the glucose impulse function. Describe briefly the glucose tolerance test and state the condition used to differentiate between a diabetic patient and a non-diabetic patient. [5 marks]

e. Sketch the graphs of blood glucose concentration and plasma insulin concentration for a non-diabetic person and a diabetic patient if both of them are given vanilla ice cream and their blood glucose rose to 250 mg/dL assuming that normally blood glucose is at 64.8 to 104.4 mg/dL. [5 marks]

4. **a.** The intracellular total chemical potential of an ion X may be defined as:

$$\mu_i^X = \mu_0^X + RT\ln[X]_i + z_X F V_i$$

where $z_X FV$ is the electrical component and all other symbols have their usual meanings. Derive the expression for the Nernst potential.

[7 marks]

b. A solution of 100 mmol/L KCl is separated from a solution of 10 mmol/L KCl by a membrane that is very permeable to K^+ ions, but impermeable to Cl^- ions. What are the magnitude and the direction (sign) of the potential difference that will be generated across this membrane? (Assume that 2.3 RT/F = 60 mV).

[8 marks]

c. The drug plasma concentration time profile can be described by the Bateman's formula:

$$C_p = \frac{FDk_a}{V_d(k_a - \lambda)}\left(e^{-\lambda t} - e^{-k_a t}\right)$$

i. Define all the symbols in the equation.

ii. Calculate the maximum plasma concentration Cp if F = 0.9, D = 600 mg, $k_a = 1\ hr^{-1}$, $\lambda = 0.15\ hr^{-1}$ and the $V_d = 30$ L.

[10 marks]