UNIVERSITY OF GHANA

BSC. ENGINEERING

FIRST SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF BIOMEDICAL ENGINEERING

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

INSTRUCTIONS:
ANSWER QUESTION 1 (SECTION A) AND TWO OTHER QUESTIONS FROM SECTION B (I.E. A TOTAL OF 3 QUESTIONS)

TIME ALLOWED: TWO (2) HOURS

SECTION A

COMPULSORY QUESTION – ANSWER QUESTION 1

1. **a.** On the same axis sketch the concentration time profile of a drug in the plasma and briefly explain the nature of each curve if the drug is administered via:

   i. Absorption
   ii. Bolus intravenous injection
   iii. Continuous infusion

(10 marks)

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

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

Calculate the maximum plasma concentration C_p if the bioavailability of the drug is 0.9, dose = 600 mg, absorption rate = 0.2/hr, elimination rate = 0.15/hr and the volume distribution = 30 L.

(8 marks)

c. The rate at which the drug accumulates in the urine is given by:

$$\frac{dM}{dt} = k_r V_a C$$

where k_r is the renal transfer rate, V_a is apperate volume and C is the concentration of the drug.

Considering bolus intravenous injection of the drug, show that the mass of the drug in the urine at any time is:

$$M(t) = \left(\frac{k_r C_o V_a}{k_{te}}\right)\left(1 - e^{-k_{te} t}\right)$$

where k_{te} is the total elimination pathway.

If the only drug elimination pathway is through the kidneys, show that the total amount of drug collected in the urine is equal to the total drug dose.

(10 marks)

d.

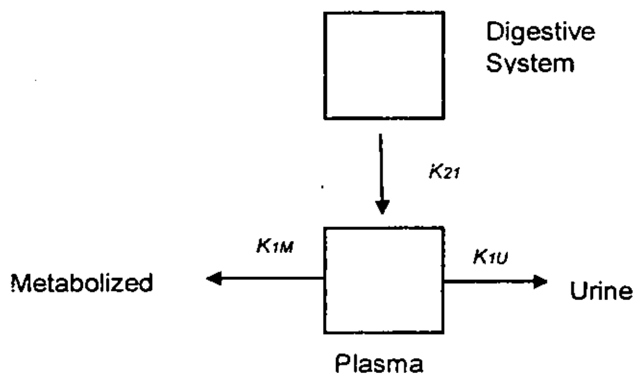

Figure 1

i. Establish the differential equations that describe the injection of a solute in the digestive system and the removal of the solute via metabolism and excretion in urine as modeled in the two compartments shown above in Figure 1. **(4 marks)**

ii. Write the solution of these equations. **(4 marks)**

iii. Sketch the plasma concentration – time graph of your solution and explain the nature of your graph. **(4 marks)**

SECTION B

ANSWER ANY TWO (2) QUESTIONS FROM THIS SECTION

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

$$\frac{d^2 g}{dt^2} + (p_1 + p_4)\frac{dg}{dt} + (p_2 p_3 + p_1 p_4)g = p_4 J + \frac{dJ}{dt} \quad \text{......... (1)}$$

where p_i (i = 1,2,3,4) are positive constants, J is the rate of glucose infusion from intestines.

If equation (1) is rewritten as:

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

where α is the decay constant, ω is the natural frequency of the subject and Q(t) is the glucose impulse function.

a. If the impulse function assumed a Dirac-delta function, write the solution for the equation. **(5 marks)**
b. Write the equations for the possible outcomes after running a glucose tolerance test. State any assumption(s) that you made. **(8 marks)**
c. Express the decay constant, the natural frequency and the impulse function in terms of the positive constants p_1, p_2, p_3, p_4 and the infusion rate J. **(9 marks)**
d. What is the period of oscillation in terms of the positive constants? **(4 marks)**
e. Use the period of oscillation to distinguish between a normal person and diabetic patient according to the diabetologist's theory. **(4 marks)**

3. The Table below 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.

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)**

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

4. A biological cell membrane can be modelled as an electrical potential.

a. Explain **three** electrical properties exhibited by the cell membrane. **(9 marks)**
b. Draw the circuit model of a cell that is permeable to potassium, sodium and chlorine. **(4 marks)**
c. Derive the expression for the current in the circuit using the Kirchhoff's voltage law (KVL). **(5 marks)**
d. Explain why Biological membranes are not in thermodynamics equilibrium. **(3 marks)**
e. Both the Nernst and the Goldman (GHK) equations are used to calculate the membrane potential of a cell. What is/ are the major difference(s) between the two equations. **(5 marks)**
f. Write the flow equations for an ion permeable to a cell membrane and define all your symbols. **(4 marks)**