UNIVERSITY OF GHANA

DEPARTMENT OF BIOMEDICAL ENGINEERING

FIRST SEMESTER EXAMINATIONS: **2013 / 2014**

LEVEL **400**: BACHELOR OF SCIENCE IN BIOMEDICAL ENGINEERING

BMEN 401: ENGINEERING PRINCIPLES OF HUMAN PHYSIOLOGY AND ANATOMY (**2 Credits**)

Total Marks: **100**. Time allocation: 2 Hours

ATTEMPT **FOUR** QUESTIONS

(a) Compartmental model predicts that the concentration of the drug in each compartment is a function of time. Write down the general expression of the concentration of the drug as it flows from one compartment to another; assume a linear and a continuous model.

(6 marks)

(b) State three assumptions made when describing the transport of a solute by diffusion between any two compartments.

(6 marks)

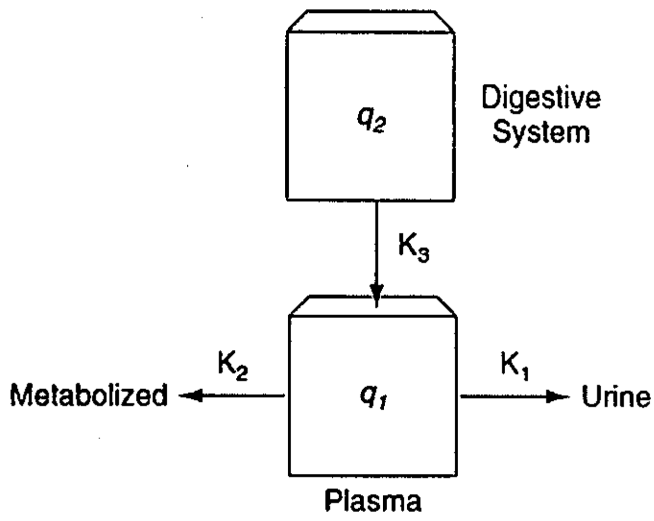
(c) Suppose 100 g of solute is ingested. Find the maximum solute in the plasma, if the quantity of solute $\mathbf{q_1}$ at a time **t** in compartment 1(the plasma) in the figure 1 below is given by the expression

$$q_1 = \frac{q_2(0)k_3\left(e^{-k3t}\right) - e^{-(k_1+k_2)t}}{k_1 + k_2 - k_3}$$

where k_1, k_2 and k_3 are transfer rates.

Determine the maximum solute in the plasma and state all the assumptions made.

(13 marks)



(Use $k_1+k_2 = 0.01$ /min, $k_3=0.04$ /min.)

Figure 1

2 (a) What is the extraction ratio of a dialyzer? Write down its expression and define the symbols used. (4 marks)

(b) (i) Write and define the symbols in the Stokes equation as applied to blood flow.

(3 marks)

(ii) Write down the solution of the Stokes equation in angular and radial components. (4 marks)

(iii) Give two reasons why the application of stokes equation to blood flow is contentious. (4 marks)

(c) Using one example, explain the importance of feedback mechanisms in human physiological system. (5 marks)

(d) Draw a flow chart to illustrate the blood –glucose feedback mechanism. (5 marks)

3(a) The diagram below (figure 2) is a three compartment model used to describe the time course of steroid concentration in the arterial and venous blood. The steroid is injected as a bolus into the pulmonary artery. Assume all metabolisms of steroids takes place in the liver, and that the metabolic rate of steroids is directly proportional to the concentration of steroids in the tissue compartment, $\dot{Q}$ is the cardiac output. If 5% of the total cardiac output flows into the hepatic artery and 20% of the cardiac output flows into the portal vein, write the differential equations for each compartment that describe the system.

(15 marks)

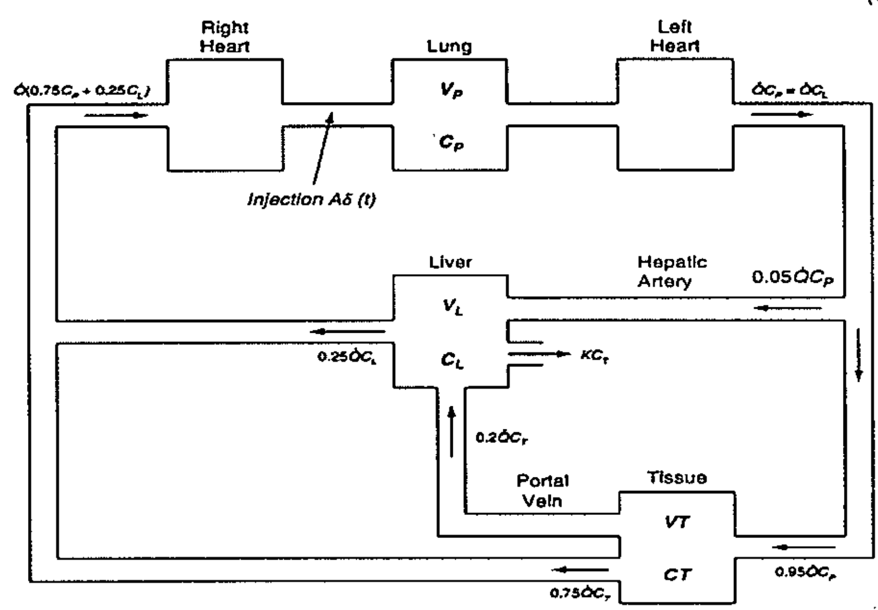


Figure 2

Where the following symbols are defined as:

$A\delta(t)$ = bolus of steroid

$\dot{Q}$ = cardiac output

c_p = concentration of steroid in lung

c_L = concentration of steroid in liver

c_T = concentration of steroid in tissue

V_p = volume of lung compartment

V_L = volume of liver compartment

V_T = volume of tissue compartment

K = metabolic rate factor

3(b) State four advantages of mathematical or computational modeling in Physiological systems.

(4 marks)

(c) According to the Poisseuille equation, the flow rate Q in a blood vessel is proportional to what powers of the radius and the length? (In otherwise if $Q \propto R^a L^b$ what are the numerical values of a and b. (6 marks)

4(a) The simplest linear circulatory model by Guyton is represented as a closed loop with two compliance vessels and one pure resistive vessel as shown below in figure 3;

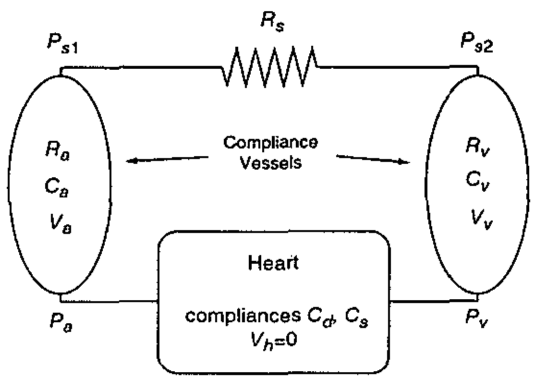


Figure 3

If the solutions of the equations (where symbols have their usual definitions) describing the system are given as:

$$P_a = \frac{(1 + FC_d R_s)V_t}{C_v + (1 + FC_d R_s)C_a}$$

$$P_v = \frac{V_t}{C_v + (1 + FC_d R_s)C_a}$$

$$Q = \frac{FC_d V_t}{Cv + (1 + FC_d R_s)C_a}$$

Discuss the qualitative features of circulation that can be seen from these solutions if:

(i) The heart rate increases.
(ii) The heart rate falls
(iii) There is an increase in the systemic resistance.
(iv) Explain what happens during heart failure based on the solutions above

(20 marks)