UNIVERSITY OF GHANA

FIRST SEMESTER EXAMINATIONS: 2012/ 2013

LEVEL 400: BACHELOR OF SCIENCE IN ENGINEERING

BIEN 405: TRANSPORT PROCESS IN LIVING SYSTEMS (2 Credits)

TIME ALLOWED: **TWO (2) HOURS**

INSTRUCTIONS: Answer **ALL** questions. Each major question carries **25 marks.**

1. Use the Goldman's equation to calculate the membrane potential V_m at rest and during action Potential for a Cockroach leg muscle. Use Keynes measured relative permeability (P) values for frog in the table below.

	OUT/ mM	IN/ mM	P resting potential	P at action potential
K^+	27	110	1	1
Na^+	111	27	0.04	20
Cl^-	150	44	0.45	0.45

Assume R= 8. 314 JK^{-1} mol^{-1}, F = 96485 C mol^{-1}. At a temperature of 27° C. (10 marks)

b. Calculate the total electrochemical energy released if a mole sodium ion Na^+ passes through a membrane given that the concentration outside the membrane is 140 mM and inside the gradient is 10 mM. Take R= 8.3 JK/mol, Faradays constant = 96485 J/mol, temperature = 37 °C assume the membrane potential Vm in a mammalian cell to be -70 mV.

c. If the transport of glutamic acid is mediated by Na^+ cotransport, how many sodium ions are needed to provide the free energy to transport a molecule of glutamic acid from a concentration of 0.1 mM outside the cell to 20 mM inside the cell? At pH of 7, glutamic acid molecules carry a net charge of **minus 1.**

2. The main bioheat transfer equation used in most model is the Pennes equation given as

$$\rho C_p \frac{\partial T}{\partial t} = \nabla(k\nabla T) + W_b C_b (T_a - T) + Q_m + Q_e$$

Explain what each term in the equation represents. (5 marks)

b. What does the numerical solution of the above equation mean? (3 marks)

c. What is the effect of the skin temperature on the blood perfusion rate. (2 marks)

d. Other factors like skin humidity and radiation emissivity of the skin that determines the skin temperature are incorporated into the boundary conditions (BC) at the skin surface. Write the generalized boundary condition for heat transfer at the skin surface and state what each term in your equation represents.

(6 marks)

3a. What is fever? Mention two clinical importance of fever. (5 marks)

b. Explain how a normal healthy human is able to maintain a constant body temperature.

(6 marks)

c. How many food calories of energy will be lost in an hour if a man is standing outdoors on a cold February morning given that:

Body temperature θ = 37°C, Air temperature θ= 0°C. Estimated surface of the human body is 1.5 m^2, emissivity e = 0.70 and σ = 5.67 x 10^{-8} watt/m^2K^4. Given that 4186 Joules =n 1 calorie.

(6 marks)

d. In modeling of the human body and thermal comfort, there are many mathematical models on the heat transfer in different tissues of the human body. State five assumptions on which these models are developed.

(5 marks)

4a. The equation for the velocity, v, at radius r of a Newtonian fluid in a tube of outer radius R under laminar flow condition is

$$v = \frac{R^2}{4\mu}\frac{\Delta p}{L}\left(1-\left(\frac{r}{R}\right)^2\right)$$

where μ is the viscosity and $\frac{\Delta p}{L}$ is the pressure drop per unit length.

Assuming that the shear stress is given by $\tau = \mu\left(\frac{dv}{dr}\right)$.

Derive an equation for the shear stress as a function of radius. (8 marks)

b. Sketch the distribution of shear stress across the diameter of the tube, and show that it is zero at the centerline and highest at the wall. (5 marks)

c. The mean velocity in an artery of internal diameter 5 mm is 0.5 ms-1. Assuming that the viscosity of blood is 0.004 Pa s and a density of 1000 kg m-3. Calculate the Reynolds number and deduce whether the flow is laminar or turbulent. (5 marks)

d. Write a short paragraph describing the differences between laminar and turbulent flow, and name two physiological conditions under which turbulent flow might arise in the body.

(7 marks)