Bioengineering Study Program – School of Life Science and Technology – ITB

Final Exam

BE-2101 Introduction to Bioengineering

(Pengantar Rekayasa Hayati)

Date: December 12, 2017

Hours: 10.00 – 12.00 (120 minutes)

Closed book and notes. Only text book of Bioengineering Fundamentals (Ann-Saterbak et al) is allowed be opened

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1. In the human circulatory system, large vessels split into two (bifurcate) or more smaller vessels in progression from the aorta to the arterioles and finally the capillaries. In returning blood to the heart, the capillaries join to form venules, and then finally the vena cavae. The diameter of each type of vessel and the blood velocity are given in the Appendix (Table D.9) (10 Poin)
    a. Calculate the volumetric flow rate and mass flow rate of blood through each of these regions of the body. State all your assumption.
    b. Calculate the Reynold number for each of the regions. The density of blood is 1.056 g/mL and the viscosity of blood is 0.040 g/(cm.s).

2. You are to prepare a 2.0 mL sample of diluted drug for injection. The total amount of drug to be injected in this 2.0 mL injection is 0.0210 mg drug/ (kg body mass). The patient's body mass is 70.0 kg. The label tells you that the volume of solution in the drug bottle is 30.0 mL. The total mass of drug in the bottle is 294 mg, and the rest is saline (salt solution). In addition to this bottle of concentrated drug, you have an unlimited supply of pure, sterile saline. (15 Poin)
    a. What is the concentration (in mg/mL) of drug in the bottle?
    b. What volume of concentrated drug (in mL) and what volume of saline (in mL) will you combine to make 2.0 mL of the drug solution of the necessary concentration?
    c. The molecular weight of the drug is 15,000 g/mol. What is the molarity of the injection?

3. Water and solids enter and leave the human body through various means. The masses of water and solids for an average man for one day are shown in **Figure 2.19**. (10 Poin)

a. Write an algebraic accounting statement for the total solids in the system. Is the system open or closed, steady-state or dynamic, reacting or non-reacting? Calculate the total solids entering and leaving the system.

b. Write an algebraic accounting statement for water in the system. Is the system is open or closed, steady-state or dynamic, reacting or non-reacting? Plug the mass of water entering, leaving, and being generated in the system into the algebraic accounting statement.

4. The body needs a constant supply of energy in order to survive. The minimum level of energy required just to perform chemical reactions in the body and maintain essential activities of the central nervous system, heart, kidney, and other organs is known as the basal metabolic rate (BMR). However, if an individual is to engage in such activities as eating and walking, additional energy must be available. On average, an individual performing normal daily activities expends 2750 kcal/day. The daily energy expenditure is comprised of maintaining the BMR, digesting and processing food (220 kcal), nonexercise activities such as maintaining body temperature (190 kcal), and purposeful physical activity (690 kcal). (15 Poin)
   a. Given that breathing accounts for 5% of the BMR, calculate the energy required for an individual at rest to breathe. Report your answer in units of joules/breath
   b. Heavy exercise can increase the daily expenditure to 7000 kcal. In addition, exercise can increase the energy requirements for breathing about 20-fold. Calculate the energy expended for purposeful physical activity when exercising.

5. **Thermal resistance of composite wall.** In the composite wall of Figure 1.6.2, the brick thermal resistance is 0.0085ºC sec/(N m), the concrete block thermal resistance is 0.0030ºC sec/(N m), and the window thermal resitance is 0.0195ºC sec/(N m). What is the thermal resistance of the wall? If the inside temperature is maintained at 22ºC, what is the heat flow through the wall when the outside temperature is 0ºC? How much heat flows through the window? How large is the electric heater that is need to mantain a temperature inside at 22ºC when the outside temperature is 0ºC? (20 poin)

6. **Oxygen balance**. A person runs on level ground at 4.47 m/sec and requires 6.7×10^{-5} m^3 O_2/sec. Maximum oxygen consumption for the young male runner is 4.2×10^{-5} m^3 O_2/sec. If the maximum oxygen debt is 9×10^{-3} m^3 O_2, how long can the running be sustained? Assume that young woman have maximum oxygen consumptions and oxygen debts 70% as large as those of their male counterparts. How long can they sustain the same rate of exercise? If the efficiency of repayment of the maximum oxygen debt is 50% (twice as much O_2 required as actually repaid), and the normal oxygen consumption at rest is 5.0×10^{-6} m^3/sec, what is the minimum amount of time required to repay the maximum oxygen debt? (15 poin)

7. **Composite membranes.** Membrane systems are used in a wide variety of situations to separate various chemical species. They are used in the pharmaceutical, biotechnology, and food insdustries, for wastewater treatment, for producing potable water, and for encapsulating artificial organ. Composite membranes are produced whre the membrane of choice must be strengthened by the addition of a second material. Assume a hollow fiber membrane of inside diameter 1.2 mm and outside diameter 1.3 mm. Mass diffusivity of the target species through this membrane is 3.0×10^{-10} m^2/sec. A second material is layered on the outside of the first material to add strength. Mass diffusivity of the same target material is 18×10^{-10} m^2/sec. What thickness of the outside material can be added if the total diffusion resistance does not exceed the resistance of the inner material by more than 25%? (15 poin)