UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCES AND ENGINEERING

Final examination

CHE 123S: Engineering Biology

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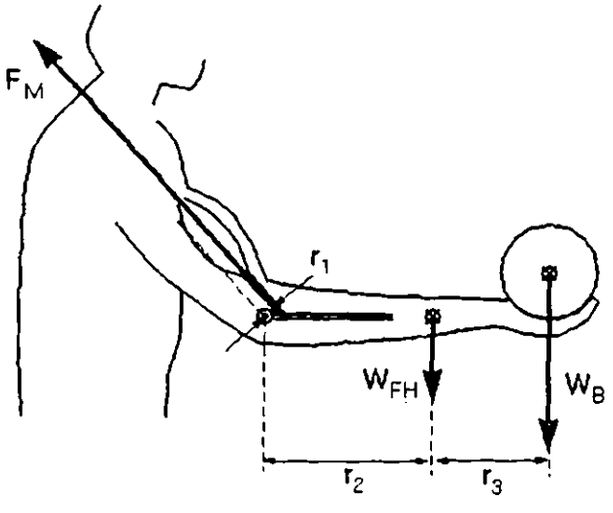
Answer all questions
All questions are of equal value

1. The sketch below shows a person holding a ball in a static position. W_{FH} and W_B are the weights of the forearm + hand and of the ball, respectively. If r_1 = 0.04 m, r_2 = 0.21 m, r_3 = 0.23 m and W_{FH} = 24 N, and if the maximum force that the muscle can exert is F_M = 2500 N, calculate the mass of the heaviest ball that the person can hold statically in the position shown. The upper arm is at angle of 135° relative to the horizontal.



2. Acyclovir (225.1 g/mole) is an antiviral drug used in the treatment of herpes simplex and other diseases. The plasma concentration increased during a 1 hour intravenous infusion of 175 mg/hour to reach a concentration of 20 μmole/L at the end of the infusion; the initial drug concentration was zero. The infusion was stopped and the drug was eliminated by a combination of metabolism and urine excretion reaching 1 μmole/L, four hours after the infusion was stopped (5 hours total after the beginning of the experiment).

Acyclovir distributes uniformly into plasma and the target tissues such that the plasma concentration is representative of tissue concentration. However, it does not distribute into all tissues so that the volume of distribution cannot be assumed to be the body volume. Metabolism and urine excretion can be lumped together into a single rate of elimination.

(a) Calculate the volume of distribution of acyclovir.
(b) What infusion rate is necessary to maintain a plasma concentration of 25 μmol/L?

3. An enzyme, chymotrypsin, is chemically immobilized onto and within porous plastic beads to make it easier to use in a commercial process. The beads are roughly 200 μm in diameter so that it is easier to remove (and reuse) the immobilized enzyme than the free enzyme. The effect of substrate (N-acetyl-L-tyrosine ethyl ester) concentration [S] on the reaction velocity, v, is given in the table below for the immobilized and free enzyme. The same amount of enzyme was used in the two cases, although it may have lost some biological activity upon immobilization.

   (a) Estimate K'_m and V_m for the immobilized and free enzyme; graph paper is supplied
   (b) Explain why the values are the same and/or different
   (c) What would happen if the beads were made much smaller, say about 10 μm in diameter.

Immobilized		Free	
[S], μmol/cm^3	v, μmol/cm^{3}s	[S], μmol/cm^3	v, μmol/cm^{3}s
0.22	0.105	0.41	1.43
0.53	0.24	0.88	2.90
0.98	0.45	2.19	4.60
2.38	1.01	4.63	7.40
4.38	1.74		

4. DNA transcription is regulated through a balance between activators that increase the rate of transcription and 'repressors' (i.e., inhibitors) that lower the rate of transcription. Both are proteins so that they are also products of DNA transcription. Consider an overly simplified situation where only a repressor is present. The rate of DNA transcription (x) is dependent both on the concentration of repressor (y) and the overall need for protein p:

$$x = 3\frac{p^2}{y^{0.6}}$$

The concentration of repressor is in turn dependent on the rate of DNA transcription:

$$\text{for } x < 0.5 \quad y = 0.002$$
$$\text{for } x \geq 0.5 \quad y = 0.002x + 0.001$$

(a) calculate the open loop gain for p = 1

(b) calculate the effect of a doubling in p, with and without the changes in repressor concentration

5. (a) A porpoise sends an echolocating pulse (60 kHz) as it tracks the path of a shark. The power associated with the pulse is 3×10^{-2} watts. The intensity of the pulse at the position of the shark is 1.5×10^{-5} W/m^2. What is the distance between the shark and the porpoise.

(b) For the following problem, indicate what you need to know in order to solve the problem. Alternatively, identify and explain the critical step in this problem. Do not actually solve it.

Many drugs are coated with a protective plastic to enable them to pass through the stomach without being degraded by the low pH that is present there. By careful design of the plastic, the drugs start to dissolve only in the neutral pH of the intestines. Calculate the fraction of drug that has dissolved after travelling a distance of 5 m in the intestines at a velocity of 1 cm/min. The rate of dissolution is first order in drug mass. Assume the initial mass of drug is 100 mg and the rate constant for dissolution is 0.001 min $^{-1}$.

Formulas for exam

$$j_i = -D\frac{\Delta c}{l} \qquad \mu = \frac{\mu_{max} C_i}{K_i + C_i}$$

$$\ln\frac{X}{X_o} = \mu\theta$$

$$v = \frac{V_m[S]}{K'_m + [S]} \qquad \frac{1}{v} = \frac{1}{V_m} + \frac{K'_m}{[S]V_m}$$

$$C_2 = C_1^o \frac{V_1}{V_2}\frac{e^{-k_a t} - e^{-k_e t}}{(k_e - k_a)}$$

$$\Delta x' = \frac{\Delta x}{1 - G_1 G_2} = \frac{\Delta x}{1 - OLG} = \frac{\partial f}{\partial y}\Delta y + \frac{\partial f}{\partial p}\Delta p$$

$$h = \frac{v^2}{2g} = c\left[\frac{F_{eq}}{W} - 1\right]$$

$$y = y_o \sin 2\pi\nu(t - \frac{x}{V})$$

$$E = 2\pi^2 \rho \nu^2 y_o{}^2 V \qquad L = \log_{10}\frac{I}{I_o}$$

$$I = P/4\pi a^2$$