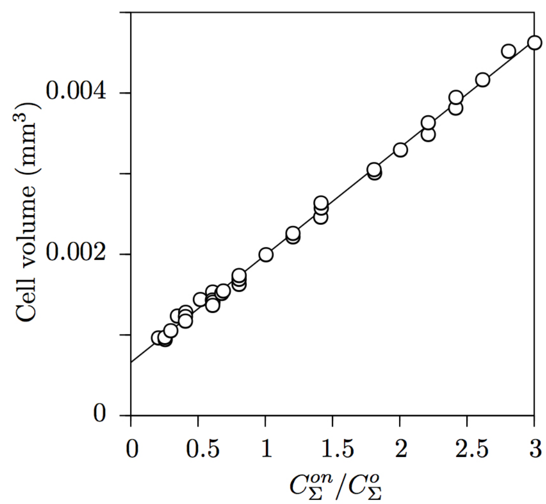
BPHS 4080 (Winter 2018) - Midterm Exam **Name:**

Instructions:

- Show all work clearly in order to get full credit. Points can be taken off if it is not clear to see how you arrived at your answer (even if the final answer is correct).
- Circle your final answers.
- Please keep your written answers brief; be clear and to the point.
- This test has 3 problems (plus an extra credit problem) and is worth 100 points (with extra credit points possible). It is your responsibility to make sure that you have done all the problems!
- You are allowed a formula sheet to bring with you. It must be a single hard copy sheet of paper (though you can write on front and back). You **must turn such in with your exam**.
- A basic handheld calculator (including graphing calculators) is allowed for this exam.

1. (*30 points*)

A cylindrical cell is bathed in solutions of a single impermeant substance that does not ionize. For each solution, the concentration C^o_Σ of the impermeant substance and the equilibrium cell volume are measured and the results are shown in the following figure where C^{on}_Σ represents the isotonic concentration.



a. Estimate the isotonic volume of the cylindrical cell.

b. Assume that the cell volume V_c contains a portion V^i that consists of water that isosmotically active and a portion V_c' that is osmotically inactive. Estimate V_c' and explain the basis of your estimate.

c. Assume that $C_{\Sigma}^{cn} = 200$ mosm/L and that the cell membrane is impermeable to NaCl. Estimate the equilibrium cell volume that would result if the cell were bathed in a solution of NaCl with concentration 200 mmol/L. Explain your reasoning.

d. Assume that the cell bath is changed from an isotonic solution to a 200 mmol/L KCl solution at time $t = 0$. Sketch the time course for equilibration of the cell volume indicating numerical values where possible. List the physical parameters of the cell that influence the time course.

2. (*30 points*)

A monosaccharide, M, is known to be transported through a cell membrane by a carrier, so that

$$\phi_s = \phi_{max}\left(\frac{c^i(t)}{K + c^i(t)} - \frac{c^o}{K + c^o}\right),$$

where $c^i(t)$ is the intracellular concentration of M, c^o is the external concentration of M, ϕ is the outward flux of M (mol/cm$^2\cdot$s), and ϕ_{max} is the maximum flux with which the carrier system is capable of transporting M. The area of the cell, A, is 10^{-6}cm^2, and K is 100 mmol/L. The following experiment is performed: The cell initially contains zero moles of M, and at $t = 0$ the cell is placed in an isotonic solution containing a concentration of M equal to c^o (constant), where $c^o \ll K$. The internal concentration of M is found to be

$$c^i(t) = c^o(1 - e^{-t/\tau}), \qquad t \geq 0,$$

where $\tau = 100$ s. The volume of the cell remains roughly constant at 10^{-10} ml throughout the experiment. Determine ϕ_{max}.

3. (*20 points*)

A solute n diffuses through a membrane that separates two compartments that have different initial concentrations. The concentrations in the two compartments as a function of time, $c_n^a(t)$ and $c_n^b(t)$, are shown in Figure   The volumes of the two compartments are $\mathcal{V}_a$ and $\mathcal{V}_b$. Is $\mathcal{V}_a > \mathcal{V}_b$, or is $\mathcal{V}_a < \mathcal{V}_b$? Explain.

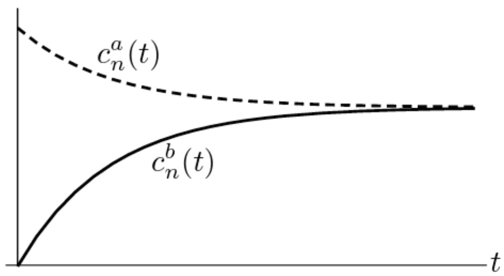


Figure   Concentration of solute n as a function of time in compartments a and b

4. (*20 points*)

Let $f(x,t)$ be the solution to the diffusion equation

$$\frac{\partial f(x,t)}{\partial t} = D\frac{\partial^2 f(x,t)}{\partial x^2}.$$

Show that the solution to the modified diffusion equation

$$\frac{\partial g(x,t)}{\partial t} = D\frac{\partial^2 g(x,t)}{\partial x^2} - \alpha g(x,t)$$

can be expressed as

$$g(x,t) = f(x,t)e^{-\alpha t}.$$

Extra Credit

Determine an expression for f based upon the following figure:

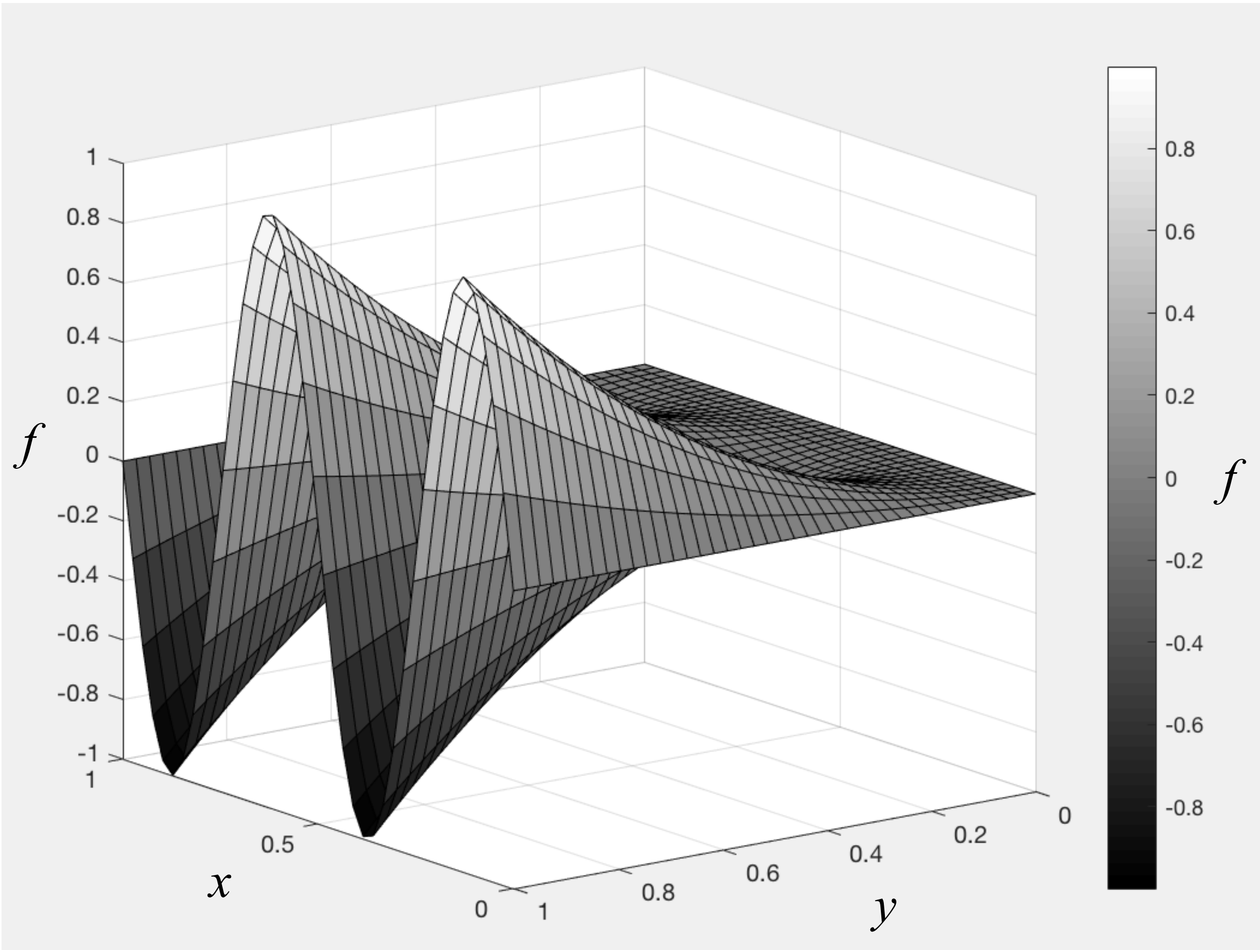


Figure 1